

# Missouri University of Science and Technology

## Graduate Catalog

### 2020-2021

Missouri S&T publishes an electronic catalog available at <http://catalog.mst.edu>.

All statements in the publication are announcements of present policies only and are subject to change at any time without prior notice. They are not to be regarded as offers to contract.

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# MISSOURI S&T

## Statement of Affirmative Action

It is the policy of the Missouri University of Science and Technology to provide full and equal employment opportunities to all persons without regard to race, color, national origin, ancestry, religion, sex, sexual orientation, gender identity, gender expression, age, genetic information, disability or protected veteran status; to prohibit discrimination in recruitment, employment or conditions of employment, including salary and benefits related thereto; to promote employment opportunity and to take affirmative action in this regard.

### Title VI of the Civil Rights Act of 1964

"No person in the United States shall, on the ground of race, color, or national origin, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

### Title IX of the Education Amendments of 1972

"No person in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education program or activity receiving Federal financial assistance."

### Section 504 of the Rehabilitation Act of 1973

"No otherwise qualified handicapped individual in the United States...shall, solely by reason of the handicap, be excluded from the participation in, be denied the benefits of, or be subject to discrimination under any program or activity receiving Federal financial assistance."

### Section 303 of the Age Discrimination Act of 1975

"No person in the United States shall, on the basis of age, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any program or activity receiving Federal financial assistance."

## The Americans with Disabilities Act of 1990 Section 102 Discrimination

General Rule – No covered entity shall discriminate against a qualified individual with a disability because of the disability of such individual in regard to job application procedures, the hiring, advancement, or discharge of employees, employee compensation, job training, and other terms, conditions, and privileges of employment.

Missouri S&T conducts its programs and activities involving admission and treatment of students, employment, teaching, research, and public service in a non-discriminatory manner as prescribed by Federal law and regulation.

Inquiries concerning the above may be addressed to:

Neil Outar, J.D., Campus Title IX Coordinator and Chief Diversity Officer  
203 Centennial Hall, Missouri University of Science and Technology  
<http://equity.mst.edu/>

Benjamin White, Director, Title IX Deputy Coordinator  
203 Centennial Hall, Missouri University of Science and Technology

Dr. Mohammad Dehghani, Chancellor, Missouri University of Science and Technology

Rolla, Missouri 65409-9957

## Accreditation

Missouri University of Science and Technology is accredited by the Higher Learning Commission:

30 North LaSalle Street  
Suite 2400  
Chicago, Illinois 60602-2504  
314-263-0456  
<http://www.hlcommission.org/>

Further information on specialized accreditation by department is available at the Office of Institutional Data website at <https://data.mst.edu/>.

## Registrar's Office Contact Information

103 Parker Hall  
300 W. 13th Street  
Rolla, MO 65409  
573-341-4181  
Email [registrar@mst.edu](mailto:registrar@mst.edu) or visit <http://registrar.mst.edu>

## Educational Goals of Missouri S&T

Missouri University of Science and Technology's mission is to integrate education, research and application to create and convey knowledge that serves our state and helps solve the world's great challenges. In a world growing increasingly dependent on science and technology, tomorrow's graduates must be prepared to lead beyond their chosen professions. They must also be leaders in business, in government, in education and in all aspects of society. Missouri S&T is dedicated to providing leadership opportunities for its students. Missouri S&T provides a full range of engineering and science degrees, coupled with business and liberal arts degrees and programs that are vital to the educational experience, regardless of major.

Missouri S&T is nationally recognized for its excellence in engineering and science education and research, and is distinguished for producing important research and key technologies vital to the economic success of Missouri and the nation. Missouri S&T's distinguished faculty is dedicated to the teaching, research and creative activities necessary for scholarly learning experiences and advancements to the frontiers of knowledge. The university's excellent physical facilities support the best possible education in the liberal arts, humanities, engineering, science, applied science and selected interrelated fields.

Missouri S&T's programs in science, engineering and business, its technology transfer programs, its leadership opportunities, and its learning environment are all integral parts of the total educational package available.

## Mission Statement

Missouri S&T integrates education, research and application to create and convey knowledge that serves our state and helps solve the world's great challenges.

## Vision

Missouri S&T will be the leading public technological research university for discovery, creativity and innovation.

## Administrators

### University of Missouri Board of Curators

**Julia G. Brncic**, 1-1-2021 (chair)  
**Darryl M. Chatman**, 1-1-2023  
**Maurice B. Graham**, 1-1-2021 (vice chair)  
**Greg E. Hoberock**, 1-1-2023  
**Jeffrey L. Layman**, 1-1-2023  
**Philip H. Snowden**, 1-1-2021  
**David L. Steelman**, 1-1-2020  
**Robin R. Wenneker**, 1-1-2025  
**Michael A. Williams**, 1-1-2025

### Missouri University of Science and Technology Administrators

**Mohammad Dehghani**, Chancellor  
**Mark Bookout**, Interim Chief Information Officer  
**Richard K. Brow**, Interim Deputy Provost, Academic Excellence  
**Kathleen Drowne**, Interim Vice Provost and Dean of College of Arts, Sciences, and Business  
**Caprice Moore**, Acting Vice Provost, Global Learning  
**Joan M. Nesbitt**, Vice Chancellor, University Advancement  
**Kathryn Northcut**, Interim Vice Provost, Academic Support  
**Neil Outar**, Chief Diversity Officer  
**Cuba Plain**, Interim Vice Chancellor, Finance and Operations  
**Stephen P. Roberts**, Interim Provost and Executive Vice Chancellor, Academic Affairs  
**Debra Robinson**, Vice Chancellor, Student Affairs  
**Shobi Sivadasan**, Vice Provost and Dean, Enrollment Management  
**Constantinos Tsatsoulis**, Vice Chancellor for Research and Dean of Graduate Studies  
**Richard W. Wlezien**, Vice Provost and Dean, College of Engineering and Computing

### Missouri S&T Board of Trustees

**Wayne Alexander**, (retired) SBC Southwestern Bell, San Antonio, TX  
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**Joan Woodard**, (retired) Sandia National Laboratories, Albuquerque, NM  
**Steve Wunning**, (retired) Caterpillar, Inc., Peoria, IL

### Missouri S&T Named Professorships

**Magdy A. Abdelrahman**, *Missouri Asphalt Pavement Association (MAPA) Endowed Professorship in Flexible Pavements in Civil, Architectural and Environmental Engineering*  
**Baojun Bai**, *Lester Birbeck Endowed Chair*  
**Laura Bartlett**, *Materials Science and Engineering, Robert V. Wolf Professorship in Metallurgical Engineering*  
**David M. Borrok**, *Gulf Oil Foundation Professorship*  
**Genda Chen**, *Robert W. Abbett Distinguished Chair in Civil Engineering*  
**Anthony Convertine**, *Roberta and G. Robert Couch Professorship in Materials Science and Engineering*  
**TBD**, *Fred W. Finley Distinguished Professorship of Electrical and Computer Engineering*  
**Sajal Das**, *Daniel St. Clair Endowed Chair in Computer Science*  
**Islam Eladaway**, *Hurst McCarthy Endowed Professorship in Construction Engineering and Management (CEM)*  
**Nuran Ercal**, *Richard K. Vitek/FCR Endowed Chair in Biochemistry*  
**TBD**, *Cynthia Tang Missouri Professorship in Computer Engineering*  
**Samuel Frimpong**, *Robert H. Quenon Missouri Endowed Chair in Mining Engineering*  
**Kamal Khayat**, *Vernon and Maralee Jones Endowed Professorship*  
**Ming Leu**, *Keith and Pat Bailey Missouri Professorship in Mechanical Engineering and Aerospace Engineering*  
**Frank Liou**, *Michael and Joyce Bytner Product Innovation and Creativity Professorship*  
**Robert J. Marley**, *Robert B. Koplak Professorship of Engineering Management*  
**Ronald J. O'Malley**, *F. Kenneth Iverson Chair of Steelmaking Technologies*  
**David Rogers**, *Karl F. Hasselman Missouri Chair in Geological and Petroleum Engineering*  
**Jagannathan Sarangapani**, *Rutledge-Emerson Professor in Electrical Engineering*  
**Joseph D. Smith**, *Laufer Endowed Chair in Energy*  
**TBD**, *Castleman/FCR Missouri Professorship of Discovery in Chemistry*  
**TBD**, *Maxwell C. Weiner Professorship in English and Technical Communications*  
**TBD**, *Union Pacific Foundation/Rocky Mountain Energy Co. Professorship*  
**Donald Wunsch**, *Mary K. Finley Missouri Professorship in Computer Engineering*  
**TBD**, *Schlumberger Distinguished Professor in Electrical and Computer Engineering*

**Curators' Distinguished Professors**

**Muthanna H. Al-Dahhan** of chemical and biochemical engineering  
**Harlan Anderson** of ceramic engineering (emeritus)  
**S.N. Balakrishnan** of mechanical and aerospace engineering  
**Martin Bohner** of mathematics and statistics  
**Richard K. Brow** of ceramic engineering  
**Joel Burken** of civil, architectural and environmental engineering  
**K. Chandrashekhara** of mechanical and aerospace engineering

**Ta-Shen Chen** of mechanical engineering (emeritus)  
**Franklin Cheng** of civil engineering (emeritus)  
**Alfred L. Crosbie** of mechanical engineering (emeritus)  
**Delbert Day** of ceramic engineering (emeritus)  
**Lokesh Dharani** of mechanical engineering  
**James Drewniak** of electrical engineering (emeritus)  
**Walter Eversman** of mechanical and aerospace engineering (emeritus)  
**William G. Fahrenheit** of ceramic engineering  
**Richard Hagni** of geology (emeritus)  
**Greg Hilmas** of ceramic engineering  
**Robert Landers** of mechanical and aerospace engineering  
**Don Madison** of physics (emeritus)  
**Sanjay Madria** of computer science  
**John McManus** of history  
**Ronald Olson** of physics (emeritus)  
**Michael Schulz** of physics  
**James Stoffer** of chemistry (emeritus)  
**David Summers** of mining engineering (emeritus)  
**Jay Switzer** of chemistry (emeritus)  
**Thomas Vojta** of physics  
**Wei-Wen Yu** of civil engineering (emeritus)

## Curators' Distinguished Teaching Professors

**Diana Ahmad** of history and political science  
**Don Askeland** of metallurgical engineering (emeritus)  
**James Bogan, Jr.** of arts, language and philosophy (emeritus)  
**James S. Drallmeier** of mechanical engineering  
**Xiaoping Du** of mechanical engineering (retired)  
**Kelvin T. Erickson** of electrical and computer engineering  
**Nord Gale** of biological sciences (emeritus)  
**Stephen S. Gao** of geology and geophysics  
**Larry Gragg** of history and political science (emeritus)  
**Leonard Koederitz** of petroleum engineering (emeritus)  
**Roger LaBoube** of civil engineering (emeritus)  
**Yinfa Ma** of chemistry (retired)  
**Frances Dee Haemmerlie Montgomery** of psychology (emeritus)  
**O. Allan Pringle** of physics (emeritus)  
**Jack Ridley** of history (emeritus)  
**David Riggins** of mechanical and aerospace engineering  
**V. A. Samaranyake** of mathematics and statistics  
**David C. Van Aken** of materials science and engineering (emeritus)

## Missouri University of Science and Technology

### Missouri University of Science and Technology

On January 1, 2008, the University of Missouri-Rolla became Missouri University of Science and Technology, or Missouri S&T. Our new name has helped us gain broader national recognition and gives us an identity that fits our mission as a leading technological research university.

### About the Campus

Founded in 1870 during the height of the Industrial Revolution, today Missouri S&T is building upon its heritage of discovery, creativity and innovation to inspire and prepare students of all majors to solve the world's great challenges. Originally known as the University of Missouri

School of Mines and Metallurgy, the campus was later named the University of Missouri-Rolla in 1964 and Missouri University of Science and Technology in 2008. Missouri S&T is one of the four campuses of the University of Missouri System.

The 284-acre campus is located in Rolla, Missouri, a town of nearly 20,000 in the heart of the Ozarks. The university offers bachelor of arts and bachelor of science degrees in 30 fields of study, including engineering, science, humanities, business and the social sciences. Master of science degrees are offered in 30 disciplines, the doctor of philosophy in 21 and the doctor of engineering in eight.

The Missouri S&T campus is home to more than 50 research and academic support centers. Externally sponsored program expenditures reached \$40.4 million in fiscal year 2019. In fiscal year 2019, Missouri S&T received \$49.8 million in new grant and contract awards. Missouri S&T continues to enhance its research activity through interdisciplinary collaborations of national significance.

Missouri S&T enrolls more than 8,000 students from 50 states and 55 countries. More than 70 percent of students study in engineering, science or computer fields, but Missouri S&T also offers liberal arts, humanities, social science and business degrees, as well as certification in select education fields. More than 4600 different employers, including many of the world's top companies, actively recruit S&T graduates each year. The most recent data available shows that S&T graduates with bachelor's degrees have starting salaries that average \$63,858 and post-baccalaureate graduates start at \$79,538 on average.

### Campus Life

Missouri S&T offers a number of campus living options, including fraternity and sorority houses, traditional residence halls, the residential college, and university commons. The university has more than 250 student organizations, including over 20 student design teams, a competitive NCAA Division II athletic program, student professional societies, a student radio station, and theater and music programs. Each year, Missouri S&T students help to organize one of the largest St. Pat's celebrations in the nation.

### University of Missouri System Structure and History

The four University of Missouri System campuses are located in Rolla, Columbia, Kansas City and St. Louis. Governing these campuses is the Board of Curators, whose members are appointed by the governor of Missouri and confirmed by the Missouri Senate. The president of the University of Missouri System directs and coordinates programs of all four campuses with assistance from staff in finance, business management, academic affairs, research, extension, human resources, university relations, and other university services. The activities of each campus are under the supervision of a chancellor, who directs campus affairs within policies established by the UM System Board of Curators and the president.

The UM System has a long and proud history. The first campus was established at Columbia in 1839, only 18 years after Missouri became a state. A land-grant university, the UM System is recognized as the first state university west of the Mississippi River. The university remained a single-campus institution until 1870 when the University of Missouri School of Mines and Metallurgy (Missouri S&T's former designation) was established at Rolla. Campuses at St. Louis and Kansas City were added in 1963.

On July 1, 1964, the UM System Board of Curators took action to rename the University of Missouri School of Mines and Metallurgy to the University of Missouri-Rolla.

## Student Consumer Information

Various state and federal laws, specifically the Higher Education Opportunity Act, require Missouri University of Science and Technology to provide information and notice to students on a variety of topics. In addition, Missouri S&T occasionally develops statements or policies on important matters and distributes them to all students. For a listing of official notifications that are currently provided to students visit the web at: <http://www.mst.edu/consumer-information/>.

It is a student's responsibility to know and follow current requirements and procedures at the departmental and university levels, including those described in the university's Student Academic Regulations, Student Handbook, Undergraduate and Graduate Catalogs, Residential Housing Terms and Conditions, and the Collected Rules and Regulations of the University of Missouri System.

## For More Information

If you have additional questions, contact the Director of Admissions, Missouri University of Science and Technology, Rolla, MO 65409-1060, [admissions@mst.edu](mailto:admissions@mst.edu), call 573-341-6731 or 800-522-0938 or visit <http://admissions.mst.edu>. You also may wish to contact one of the following offices for specific information:

- Alumni Affairs and Constituent Relations 573-341-4145
- Career Opportunities and Employer Relations 573-341-4343
- Counseling Services 573-341-4211
- Extended Learning 573-341-4132
- Global Learning-Distance Education 573-341-6591
- Global Learning-Professional & Continuing Education 573-341-6222
- Intercollegiate Athletics 573-341-4175
- International Affairs 573-341-4208
- Miner Wellness 573-341-4225
- Registrar 573-341-4181
- Residential Life & Student Support 573-341-4218
- Student Disability Services 573-341-6655
- Student Diversity Initiatives 573-341-7286
- Student Financial Assistance 573-341-4282
- Student Health Services 573-341-4284
- University Advancement 573-341-6900
- University Police 573-341-4300
- Vice Chancellor Student Affairs 573-341-4292

## Academic Calendar

The academic calendar can be found at <http://registrar.mst.edu/calendars> (<http://registrar.mst.edu/calendars/>).

# GENERAL INFORMATION

This section includes information about various academic, campus and extracurricular resources available to Missouri S&T students. These links include fee information, academic and extracurricular programs, student opportunities, policies, and services and support available to graduate students.

Please navigate this section by using the menu at the left and selecting the category that best represents the information you wish to view. For more comprehensive information please visit the individual department websites.

## Care Management

Care management supports students throughout their S&T experience. By identifying immediate needs, connecting with appropriate resources, and working to develop a personalized and solution-focused plan, the care manager helps students face challenges and enhance their well-being and success.

### Care Management Services Provides:

- Assistance navigating campus and community resources
- Solution-focused problem solving
- Referrals to campus and other resources
- Coordination and follow up during and after hospitalization and/or medical leaves of absence
- Crisis management
- Help managing complex medical needs
- Exploration of and referral for mental health or physical health concern

### Contact Information

Care Management Services  
Division of Student Affairs  
107 Norwood Hall  
Phone: 573-341-4209  
Fax: 573-341-6333  
E-mail: [cm@mst.edu](mailto:cm@mst.edu)  
Web: <http://caremanagement.mst.edu>

## Career Opportunities and Employer Relations (COER)

Career opportunities and employer relations (COER), located on the third floor of Norwood Hall, provides many services to assist Missouri University of Science and Technology students and alumni in their job search for professional full-time, intern (summer) and co-op employment.

COER is an effective link between Missouri S&T students and employers, and its goals are two-fold: first, to PREPARE students for conducting a successful job search, and second, to PROVIDE opportunities for employment.

## Job Search Preparation

The COER webpage, <http://career.mst.edu>, (<http://career.mst.edu>) contains information on services, career fairs, events, on-campus

interviews, and job listings, as well as on-line copies of the COER Career Guide.

### Individual Advising

Appointments are available with career advisors who work one-on-one with students to review their resume and cover letter and to discuss job search concerns.

### Seminars & Events

Seminars on resume and cover letter writing, conquering the career fair, professionalism and interviewing skills, networking, negotiating a job offer and more are presented each semester at convenient times for students.

An etiquette dinner is provided once an academic year to review dining and business etiquette.

### Practice Interviews

Practice interviews are available for students who would like to assess their interviewing skills. Students are evaluated by a career advisor and given feedback on their strengths and areas that need improvement.

## Job Search Opportunities

### Career Fairs

Multiple career fairs are sponsored each year to provide students direct access to hundreds of employer representatives. Students have the opportunity to meet face-to-face with recruiters, hand out resumes, and collect employer information. These contacts often lead to full-time, intern, and co-op interviews and employment.

### On-Campus Interviews

Full-time, intern and co-op interviews are conducted by employers in COER's professional interview suites, located on the 3rd floor of Norwood Hall. Students must be registered with COER to upload their resume into Handshake and participate in on-campus interviews. Students should check the system daily for information about employers coming to interview, job requirements, and important dates. Each student is responsible for submitting his or her resume electronically and for signing up for interviews by the stated deadlines.

### Resume Referrals

When a student registers with COER, his or her resume can be referred to employers who are interested in hiring Missouri S&T students even though the employer may not necessarily be coming to campus to interview. The employer will then contact the student directly if he or she is interested.

### Resume Drops

Some employers will list their job opportunities and request a "resume drop" from students. Interested students are responsible for making their profile and resume public through Handshake by a designated date. Resumes submitted are reviewed and students the employer is interested in will be contacted.

### Alumni

Missouri S&T alumni may also register with COER. Once registered, they will receive access to Handshake to search job listings. In addition, alumni resumes that are uploaded in the system will be sent to employers requesting resume referrals if they match their hiring qualifications. To register, contact COER at 573-341-4343.



## Council of Graduate Students

The Council of Graduate Students (CGS) is the authorized governing body for the graduate students on the Missouri S&T campus. As such, it provides a liaison between the school administration and the graduate student population. Representatives of the council serve on various committees on the campus and represent the graduate community to advocate their opinions and concerns on various campus policies. CGS deals with the procedural matters on campus and exists to share and discuss the information pertinent to all Missouri S&T graduate students. The Council of Graduate Students maintains open lines of communication with all the other governing bodies at Missouri S&T and other UM System campuses. CGS strives to maximize the quality of life, develop leadership skills and foster higher academic standards for graduate community at Missouri S&T.

All graduate students who are in good academic standing at Missouri S&T are automatically the members of Council of Graduate Students. The executive board of CGS is elected through student voting and holds office for one year. The board consists of the president, vice-president, secretary and treasurer. The department representatives are elected from each graduate degree-granting department. One representative serves for each 25 graduate students in a single department. The information on department representative and the executive board can be obtained from CGS website <http://cgs.mst.edu/>.

The office of CGS is in 218 Havener Center. You can email your inquiries to [cgs@mst.edu](mailto:cgs@mst.edu). Please visit the CGS website, <http://cgs.mst.edu>, to learn more about the organization's mission and its activities.

## Counseling Services

Counseling Services promotes self-awareness and skill development to support individual success and well-being. Counseling offers a variety of services to the Missouri S&T campus community including individual, group, and crisis counseling; consultation; care coordination; presentations and programming on many topics; the StressLess room; the Van Matre resource center of self-help materials; and the Faculty/Staff Assistance Program (FSAP).

Mental Health counseling is provided through a solution-focused brief treatment model to Missouri S&T students and benefit-eligible employees. Services are confidential within ethical and legal limitations and provided by licensed counselors and psychologists at no additional charge. Concerns commonly addressed include self-improvement, adjusting to change, coping with stress, motivation and self-management, interpersonal and relationship issues, depression and anxiety, and career development.

Group counseling is an effective, interactive, supportive, interpersonal form of therapy. Counseling Services offers many groups based on campus need and interest. Some current and past groups are Building Social Confidence, Miners for Recovery, Test Anxiety, Cognitive Behavioral Therapy, and issue-focused support groups such as ADD/ADHD, Graduate Student Support, Autism Spectrum Disorder, etc.

Counseling Services actively promotes student learning, persistence, professional development, and graduation through its outreach programming services on topics such as mental health, mindfulness, resiliency, teamwork, stress management, conflict resolution, and time management.

The Van Matre Resource Center, a self-help library, contains a wide range of materials. Topics range from communication skills to parenting, career exploration to dealing with depression, anxiety, and abuse. Materials are available for checkout.

### Faculty/Staff Assistance Program (FSAP)

FSAP provides a variety of services for benefit eligible faculty and staff such as counseling, consultation, and programming.

### Contact Information

Counseling Services  
204 Norwood Hall  
Phone: 573-341-4211  
Fax: 573-341-6179  
E-mail: [counsel@mst.edu](mailto:counsel@mst.edu)  
Web: <http://counseling.mst.edu>

## Curtis Laws Wilson Library

The Curtis Laws Wilson Library provides services and materials to support the university's academic programs. In addition to providing students with research resources and skills, the library is a place for collaborative learning. Spaces are technologically enabled, with resources such as the Nonavitra visualization wall, high performance computers, and computer learning centers (CLC).

In addition to a print collection, the library provides many online full-text resources. Missouri S&T is a selective depository for United States government documents. Through interlibrary loan, the Missouri S&T collection is supplemented by materials owned by other libraries around the world.

The Curtis Laws Wilson Library is home to the Scholars' Mine, the university's online repository of scholarly contributions created by S&T faculty and students. The library provides support on campus for scholarly communications and related questions such as copyright and data management planning. The library is also home to the S&T archives.

Librarians provide direct support and consultation with students and faculty. One-on-one research consultations are welcome, and librarians meet regularly with classes and student groups.

The Curtis Laws Wilson Library is Missouri S&T's gateway to the ever-expanding world of information. Students are encouraged to explore the library's homepage at <http://library.mst.edu>.

## Fees

*"The university reserves the right to modify by increase or decrease the fees charged for attendance and other services at the University, including but not limited to tuition, at any time when in the discretion of the governing board the same is in the best interest of the University, provided that no increases can or will be effective unless approved by the governing board not less than thirty (30) days prior to the beginning of the academic term (semester, etc.) to which the fees are applicable, with all modification of fees to be effective irrespective as to whether fees have or have not been paid by or on behalf of a student prior to the effective date of the modification."*

To review the statement of financial responsibility and its terms visit <http://cashier.mst.edu/studentfees/statementoffinancialresponsibility/>. This statement allows students to confirm their understanding of financial implications when registering each semester.

## Electronic Billing Statements

Electronic billing is the official billing method for currently enrolled students at Missouri University of Science and Technology. Students will be notified by e-mail at their Missouri S&T e-mail account when monthly billing statements are available. Currently enrolled students will be able to view, print, and pay their student fee bill online at Joe'SS.

Currently enrolled students can also authorize others (parents, grandparents, guardians) to view and pay their student fee bill. Access to student account information can be granted by visiting <http://registrar.mst.edu/psinfo/additionalauthorizedaccess/>. As an additional authorized access (AAA) member, they have access to electronically view and print the monthly billing statement and make payment online. They are also notified when the statement is available at the e-mail address entered by the student during set-up. For further information, and more access options, please visit the Missouri S&T registrar's office web site at <http://registrar.mst.edu>. (<http://registrar.mst.edu>)

## Tuition per Credit Hour

All students enrolled at Missouri S&T are required to pay tuition. Visit the Missouri S&T cashier's office web site for fee information at <http://cashier.mst.edu>.

Courses audited and courses taken for reduced credit will be counted at their normal credit value in computing the amount of tuition to be paid. Students enrolling in zero credit hours are required to pay tuition and fees according to the equivalent credit for the course.

## Information Technology Fee

All students enrolled at Missouri University of Science and Technology are required to pay an information technology fee per credit hour.

## Course Fees

An additional course fee will apply to the following and will be charged per credit hour:

Engineering and sciences and computing course fees will be charged per credit hour to all students enrolled in engineering, biological sciences, chemistry, computer science, geology, geophysics and physics courses. Co-listed courses are subject to the engineering and sciences course fee.

Business and information technology course fee will be charged per credit hour to all students enrolled in business, IS&T and M&IS courses. Co-listed courses are subject to the business and information technology course fee.

## Student Activity/Facility Fee

A student activity/facility fee is charged to students each semester to pay for a variety of activities, services, and bonded debt on student fee funded buildings. The activity/facility fee is determined and approved by the Student Council. The activity/facility fee includes fees for the Havener Center, intramural and recreational facilities and programs, campus events, the student newspaper, radio station and yearbook, and funding for a variety of student organizations. The Rollamo Yearbook fee will be charged during the fall semester to all undergraduate students enrolled for seven or more hours and will remain optional for all undergraduate students enrolled for fewer than seven hours and all graduate students. Graduate students pay a fee to fund the Council of Graduate Students.

The activity/facility fee is prorated for students enrolled in fewer than ten hours.

The activity/facility fee is charged to all students, undergraduate and graduate. Students attending the Engineering Education Center in St. Louis do not pay the student activity fee.

Additional information concerning the Missouri S&T student activity/facility fee is available at: <http://studentlife.mst.edu>.

## Health Service Fee

The mandatory health service fee is charged to all students, graduate and undergraduate (full or part time enrolled) each semester. This allows students access to the Student Health Complex.

## Academic Testing Fee

An academic testing fee will be charged to all undergraduate students that have reached the level of sophomore, junior and senior. The fee will be assessed each semester at the following rates:

- Senior Fee: \$19.50 per semester
- Junior Fee: \$12.00 per semester
- Sophomore Fee: \$5.00 per semester

## Graduation Fee

A \$75 graduation fee is assessed to all students who have applied as a candidate for graduation. This fee will be charged to the student account after submitting an application for graduation.

A \$25 certificate graduation fee is assessed to all students who have applied as a candidate for completion. This fee will be charged to the student account after submitting a certificate application for completion.

## Time of Payment of Fees

All fees must be paid in full or payment arrangements made at the time of registration at the opening of each semester or term as a condition of admission to classes. Consult the academic calendar for dates of registration and payment of fees.

## Minimum Fee Payment Plan

The student's account (to include tuition and fees, housing, traffic violations, etc.) will be billed for the full amount each month with a minimum payment allowed. The minimum payment is derived by dividing the full account balance by the number of scheduled payments remaining in the semester. If a student chooses to pay the minimum amount, a 1 percent per month interest charge will be assessed on the remaining unpaid account balance.

## Late Payment Fee

Student fee accounts will be subject to a late fee for unpaid amounts billed when payment is not received by the scheduled due date as communicated on the student's monthly billing statement. If the minimum payment or billed balance due is paid on or before the scheduled due date, as it appears on the student's monthly billing statement, no late fees will apply.

Past due amounts owed to the university must be satisfied by payment in full. Failure to pay may result in transcripts or diplomas being withheld. The university will pursue appropriate collections practices which may include referrals to a collection agency for accounts that remain past

due. The account may be assessed an additional collection charge of up to 50 percent of the balance if referral to a collection agency becomes necessary.

## Fall Semester Payment Due Dates

Preregistered students: four installments due August, September, October, and November 10th.

Open registration students: the number of installments available will be dependent upon the timing of your registration.

## Spring Semester Payment Due Dates

Preregistered students: four installments due January, February, March, and April 10th.

Open registration students: the number of installments available will be dependent upon the timing of your registration.

## Summer Semester Payment Due Dates

Preregistered students: three installments due May, June, and July 10th.

Open registration students: the number of installments available will be dependent upon the timing of your registration.

## Financial Aid

Approved financial aid is applied directly to a student's account. The entry will appear as a credit on the billing statement and will reduce the current term balance due. The balance remaining after application of financial aid will be billed to the student and will be subject to the minimum payment process and interest charge calculation.

## Personal Checks

Personal checks will be accepted only for the amount due from the student. Personal checks can be presented to the cashier's office in person or by mail to G4 Parker Hall, Rolla MO 65409. A late registration fee will be assessed if a check presented in payment of student fees is returned unpaid and remains unpaid after the close of the registration period.

## Online Payment Options

Missouri S&T has convenient online payment options for our students and their authorized payers. Students can make online check and credit card payments by accessing TouchNet through their Joe'ss Student Center. Authorized payers with access to student account information will log in to <https://joess.mst.edu/> to make online payment.

The University of Missouri contracts with a third party vendor to process credit card payments applied to the student fee account. Credit card payment can be made by Visa, MasterCard, Discover and American Express online only. A convenience fee of 2.85 percent (\$3.00 minimum) will be charged by the third party vendor on all credit card payments.

To avoid the convenience fee, students and their authorized payers, have the option to make an online electronic check payment by simply entering the bank/financial institution routing and account numbers at the time of the online payment. Online payment information can be found on the cashiers website at <http://cashier.mst.edu/>.

## Debit Card Payment

PIN based debit card payments are processed at the cashier's office at no cost to the student. The student must present the card at the time of the transaction and will enter their personal identification number (PIN) to complete. Credit card payments, for payment of a student account, are not accepted at the cashier's office.

## Late Registration Fee

A student who registers after the start of the semester will be charged a late fee equivalent to one hour undergrad tuition. Also, by registering late, a student may find certain sections or entire courses closed to registration. Each department reserves the right to close sections of courses or even to close enrollment in a department when the capacity of the class is reached.

## International Student Sponsored Program

A full range of services for sponsored international students is provided through the office of international affairs. International students sponsored by international agencies receive special services and are charged an administrative fee per semester. Individual students desiring to take advantage of these special services may apply for them. Details on the current Sponsored Student program and costs are available upon request from:

Office of International Affairs  
103 Norwood Hall  
Rolla, MO 65409-0160

## Sponsor Billing

If part or all of your educational expenses are being paid by an embassy, agency or company, you can elect to have them billed directly through our sponsor billing process.

Upon receipt of written authorization, a credit will be posted to your student account for the amount authorized. We will discontinue billing you for that amount and bill your sponsor directly. If the sponsor does not pay in a timely manner, the credit will be removed from your account and you will be responsible for this amount again, including the accrual of finance charges.

Additional information is available on the cashier's website under sponsor billing.

## International Student Services Fee

The office of international affairs (IA) student services provides a full range of services to international students including, but not limited to, communication with prospective international students and applicants, issuance of immigration documents, new international student orientation as well as ongoing orientation/acclimation programs. IA manages the federally-mandated Department of Homeland Security Student and Exchange Visitor Information System (SEVIS) database and is responsible for meeting current requirements, the upcoming SEVIS II, and all follow-on phases. Due to the complexity and scope of these associated mandatory requirements, a fee has been implemented in order to meet the system demands. Therefore, all F-1 and J-1 international students who are enrolled in one or more academic hours will be charged an International Student Fee per semester for fall, spring, and summer semesters.

## Mandatory Health Insurance for International Students

All international students, as a condition of their enrollment, are required to purchase mandatory health insurance. This includes all F-1 and J-1 visa students. In addition, J-1 visa students whose spouse and/or children are living in the U.S. are required to carry health insurance. An independent carrier working through the International Affairs (IA) office, provides an insurance policy at a reasonable cost. Premiums will be charged during the fall and spring semester. Summer premiums are included in the spring semester.

For more information on the mandatory health insurance requirements for international students, contact:

International Affairs Office  
103 Norwood Hall  
573-341-4208

## Reassessment of Fees

Fees subject to reassessment include: tuition, information technology fees, engineering, science & computing, and business supplemental fees, student activity/facility fees, health service fees and any instruction-related miscellaneous fees that may be assessed.\* Students who have registered for credit courses, and made payment of fees, and whose registration is subsequently canceled, or who withdraw from the university or reduce their course load, will, subject to certain exceptions and upon written request to the registrar's office, receive a reassessment of the fees in accordance with the current fee reassessment schedule : <https://cashier.mst.edu/refund/>

### Fall/Spring Semester-16 weeks

Elapsed Days	Percent of Refund
Class days 1-5	100%
Class days 6-20	50%
Class days 21-40	25%
After class day 40	NO REFUND

### Summer Session-8 Weeks

Elapsed Days	Percent of Refund
Class days 1-3	100%
Class days 4-13	50%
Class days 14-20	25%
After class day 20	NO REFUND

Class days are counted by excluding Saturdays, Sundays and holidays.

\*Deductions may be made from any refund of fees for any financial obligation due the university.

## Examination Fee

When a graduate student takes the master's comprehensive exam, doctoral qualifying exam, doctoral comprehensive exam, or defends their thesis/dissertation during the intercession, then an examination-only fee is appropriate by enrolling in one credit hour of Oral Examination, 5040/6040. Intercession, for the purposes of this section, refers to the specific interval of time between the closing date of one academic semester/session and beginning of classes for the academic semester/session that immediately follows. If the submission of graduate Form 2/7 and final copy of the thesis/dissertation are not completed before the

next semester begins, the student must register for at least one hour of graduate research.

## Fellowships, Research Assistantships, Teaching Assistantships and Graduate Assistants

Institutional financial assistance of four types is available to graduate students at Missouri S&T: graduate teaching assistantships, graduate research assistantships, graduate assistants, and fellowships.

### Chancellor's Distinguished Fellowship

For full details refer to [http://grad.mst.edu/futurestudents/funding/cd\\_fellowship](http://grad.mst.edu/futurestudents/funding/cd_fellowship) ([http://grad.mst.edu/futurestudents/funding/cd\\_fellowship/](http://grad.mst.edu/futurestudents/funding/cd_fellowship/)).

### National Science Foundation Fellowships (NSF)

NSF fellowships are awarded to the successful applicants directly. NSF pays the fees of the fellows. Part-time teaching by NSF fellows may increase the appointment; some departments require this teaching experience.

### Graduate Teaching Assistantships

Part-time teaching is mandatory in some departments, to help students achieve professional experience and self-development. Departmental policies on this matter vary and inquiry should be made to the appropriate chair. Permissible schedules for graduate students holding part-time teaching appointments are described under "Permissible Schedules." Remuneration varies according to the number of academic hours taught. Half-time assistantships for the academic year require 20 hours per week of effort. In-state student status for fee purposes is awarded to all graduate assistants employed 25 percent time or more.

### Graduate Research Assistantships

Graduate research assistantships are offered in all departments. Half-time graduate assistant stipends may be available. Holders of assistantships devote approximately 20 hours per week to laboratory effort and are, therefore, limited to a maximum of 12 credit hours of academic study per semester. Graduate instructorships require full-time teaching effort and are appointed only under exceptional circumstances. Research credits toward a degree may require effort beyond that required of the appointment. A number of positions are available during the summer months. In-state student status for fee purposes is awarded to all graduate assistants employed 25 percent time or more.

### Radcliffe Graduate Scholarships

The geology and geophysics program offers the Radcliffe Graduate Scholarship to qualified M.S. and Ph.D. students. Contact the geology and geophysics program for further details.

### State and Federal Fellowships

Missouri S&T receives grants from various agencies. Contact your academic department for further information.

## Stephen P. Gorman Scholarship

Gorman applicants must have lived in St. Louis City or County and graduated from a St. Louis City high school. Need is a factor. An application may be obtained from the student financial assistance website <http://sfa.mst.edu>.

## Industrial Fellowships

Several industrial fellowships are available, the number varying with the problems and support given by the industry. Industrial fellowship holders are required to work part time on the project to which they are assigned. The exact amount of time is governed by the character of the project and its applicability to thesis requirements. The stipend for industrial fellowships is variable, depending on support from industry, but appointments are ordinarily effective for a year at a time. Both academic and research work may be applied as credit to fulfill the requirements of the master of science or doctor of philosophy degrees.

Complete information concerning the fellowships currently available may be obtained from the chair of the department concerned.

## Student Diversity and Academic Support Programs

The student diversity and academic support programs are designed to promote and support under-represented minority (African American, Hispanic American, and Native American) students with special emphasis on those who are pursuing engineering or science degrees.

The student diversity and academic support programs also provides opportunities for professional development activities, networking events, and opportunities to participate in regional and national conferences. Missouri S&T is also a member of the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. (GEM).

## Miscellaneous Grants and Awards

Several miscellaneous awards also are available for graduate students in various disciplines. Research programs are carried on in a variety of fields and are sponsored by such donors as the National Science Foundation, various government agencies, and industrial companies. The periods of award and the amounts of the stipends vary according to the qualifications of the applicant and the funds available.

All graduate teaching assistants, graduate research assistants, graduate assistants, fellows, and holders of industrial fellowships must pay the regular fees required for enrollment as graduate students at Missouri S&T. However, many of the fellowships do provide for payment of these fees from fellowship funds and waive out-of-state fees.

## Research Assistantships

A number of research projects sponsored by federal agencies or other donors carry graduate research assistantships. The stipends and tenures vary according to the particular grant, but they are usually comparable with other assistantship figures. Specific information can be obtained from the department involved. Recipients work on a specified research program under the supervision of a member of the professional staff.

## Other Research Assistantships

A number of research assistantships are offered each year in conjunction with Missouri S&T research centers. The research performed may

supplement other credited research in the preparation of theses and dissertations.

Applicants must have a bachelor of science degree or its equivalent, have had the proper training in the required field of study and be qualified for admittance to graduate standing while doing research work. Fellows must register as candidates for one of the advanced degrees (master of science or doctor of philosophy).

## Financial Assistance

### Our Mission

The Student Financial Assistance Office (SFA) assists families with understanding college costs at Missouri University of Science and Technology. Our team facilitates access to federal, state, institutional and private financial resources and coordinates access to university scholarship and loan awards for our students, while adhering to NASFAA's statement of ethical principles.

The SFA Office continually strives to provide high quality service to all students, families, faculty, staff, alumni and other interested parties. Our team works to meet campus strategic goals through financial aid administration, community outreach, financial literacy and debt counseling programs.

### Federal Aid Opportunities

To apply for federal financial aid, (loans and work study), you must complete a FAFSA (Free Application for Federal Student Aid). Preference will be given to those students whose FAFSA has been received by February 1. If you apply for federal financial aid at any other time of the year, Missouri S&T will attempt to fill your financial needs to the extent that funds or opportunities are available.

Federal aid is contingent upon students meeting satisfactory academic progress (SAP). SAP requirements are listed on the student financial assistance website: <https://sfa.mst.edu/resources/policies/>.

Graduate students should contact the department in which they are majoring for information for scholarships, grants, fellowships or assistantships. For more information about financial aid eligibility: <https://sfa.mst.edu/>.

## Global Learning

### Global Learning

Through distance education, S&T offers graduate programs in business, psychology, technical communication, science, technology, and engineering, of which many are nationally ranked. S&T's unique approach to delivering distance programs is designed for working professionals. Visit [distance.mst.edu](http://distance.mst.edu/) (<http://distance.mst.edu/>) for a list of graduate degrees and certificate programs offered through distance education. For more information, contact us at 573-341-6591, or email [global@mst.edu](mailto:global@mst.edu).

"Never stop learning" is the motto for professional and continuing education (PCE). We provide programs for all ages, beginning in grade school and continuing through one's professional career. Youth programs with STEM-focused learning encourages students to expand their knowledge and career choices. Professional development opportunities are promoted through technical short courses, seminars, webinars, conferences, and online training. PCE is a conduit to access knowledge

experts for program development and supports full-service event planning and logistics. For more information, contact us at 573-341-4200, email [pce@mst.edu](mailto:pce@mst.edu) or visit [pce.mst.edu](http://pce.mst.edu) (<http://pce.mst.edu/>)

For further information, contact:

Global Learning  
G8 Norwood Hall  
320 West 12th Street  
Phone: 573-341-4132  
Fax: 573-341-4992  
Web:[global.mst.edu](http://global.mst.edu) (<http://global.mst.edu/>)

## Classroom Technology

To support teaching and learning, IT supports a broad set of instructional technologies. In addition to CLCs, classroom presentation technology, such as podium computers, laptop connections, projectors, and speakers, are provided to enhance the ability of instructors and teaching assistants to present course materials and use student response systems (clickers) in the classroom.

The Media Services team is made up of professional video producers, audio technicians and graphic designers who collaborate with faculty to deliver distance education and enhance local education. We connect you to your students in the classroom and distance students around the world using the most current, cutting-edge and reliable technology. We professionally produce content for use in the classroom or for departmental programs including guest speakers, special presentation, workshops, webinars and instructional videos.

The Learning Environments team designs, implements and supports the technology that helps provide faculty and students the best possible learning experience. Our environments include 100+ classrooms, 50+ computer labs, and many full production studio classrooms. We also support numerous instructional software tools. These tools range from lecture capture and delivery, to virtual desktop environments and Canvas-our learning management system. We work directly with faculty to ensure all required software is deployed in our computer labs across campus.

## Graduate Faculty

The Graduate Faculty, acting in accordance with the Rules and Regulations of the Board of Curators and campus policy legislated by the General Faculty, is responsible for the establishment of the policies, rules and regulations governing all graduate studies on the campus.

The membership of the Graduate Faculty shall consist of the following: The President of the University of Missouri System, the Chancellor, the Provost and Executive Vice Chancellor for Academic Affairs, the Vice Provost and Dean for the College of Engineering and Computing, the Vice Provost and Dean of the College of Arts, Science and Business, the Vice Chancellor of Research and Dean of Graduate Studies, the Vice Provost for Academic Support, Chairs of departments authorized to offer graduate degree programs and/or graduate courses, and other members of the faculty at Missouri University of Science and Technology who are accepted under the rules of the Graduate Faculty to assume the responsibilities and authorities delegated to it.

Graduate Faculty membership will be approved automatically for those newly hired at a position of Assistant Professor or higher and holding the highest degree ordinarily awarded in the candidate's field. Their membership will be subject to reappointment regulations (Article IV.D).

## Information Technology (IT)

### Getting Started

Missouri S&T's information technology (IT) department provides a variety of computing tools and resources to assist with academic, research and administrative work done at the university. Students, faculty, and staff use computers daily to register for classes, communicate with friends, send email, collaborate on group projects and research, publish web pages, write reports, and find course schedules.

### Computer Accounts

Computer accounts are assigned to students and are used to access various resources at Missouri S&T, such as the computing network and the computers and software in computer learning centers (CLCs). Most Missouri S&T IT services require an authorized computer account (username and password) to gain access. The following services are available through IT computer accounts:

- Access to the campus network, including wireless networks on campus
- Google Apps, including Gmail, Drive, Sites, Google+
- High Performance Computing clusters
- Joe'SS (student web portal)
- Learning Management System (Canvas)
- Network file storage

### University Communications to Students

Each student, once initially registered for classes, will be issued a Missouri S&T email account with an address on the [mst.edu](http://mst.edu) domain. This is the account used for official university business and official university communications to students. Students are expected to check their Missouri S&T email account regularly for university communications and are responsible for communications sent to this and from this account. Therefore, communications sent to this account will be considered to have fulfilled any university obligation for notification.

Students must activate their email account online at: <http://it.mst.edu/services/email/student-email/>. (<https://it.mst.edu/services/email/student-email/>)

### Leaving Missouri S&T

Assigned computer accounts remain active and available for use as long as a student is enrolled in classes at Missouri S&T. Additional information regarding account maintenance may be found at <https://it.mst.edu/policies/> and then clicking the "username maintenance" link.

Following graduation, Missouri S&T students retain access to their student email accounts. Local account access is removed one semester after students graduate or stop attending. If the student was also employed by the university, account removal may occur sooner.

Students are responsible for creating a backup of any data on their network storage prior to leaving the university.

### Systems and Software

Missouri S&T's IT department provides a wide variety of computing and networking facilities and support. These facilities include, but are not limited to the following:

- Computer learning centers (CLCs)
- General purpose cluster computing
- HPC
- Linux systems
- Macintosh systems
- Nonavitra high definition wall
- Software for use on personal computers
- Windows-based PCs

## Computer Learning Centers (CLCs)

Computer labs, called computer learning centers (CLCs), provide computers and specialty software for students to use for in-class, homework, and project related work. AppsAnywhere is available in all CLCs.

CLCs are located in various buildings around campus. Use of computers and technology in these locations is restricted to Missouri S&T faculty, staff and students. The list of CLC locations, hours of operation, and equipment is available online at <https://it.mst.edu/services/clc/>.

Missouri S&T is now using a print management system, PaperCut NG, in campus computer labs (CLCs). Students and instructors will be given a semester printing quota sufficient for completing academic work. This initiative will help conserve paper, toner and electricity and help ensure fair use of campus printing resources. All print quota is reflected in shamrocks. It is important to note that shamrocks in no way correlate to real money. More information can be found online at <https://it.mst.edu/services/clc/clcprint/>.

The Web Print service allows users to initiate a print job from their local machine or device and then direct that print job remotely to a select few printers on campus. Once you are at the printer, you can simply retrieve your print job and have it print while you are there at the printer. You can find more information online at <http://it.mst.edu/services/clc/clcprint/webprint/>.

## Classroom Technology

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The Learning Environments team designs, implements and supports the technology that helps provide faculty and students the best possible learning experience. Our environments include 100+ classrooms, 50+ computer labs, and many full production studio classrooms. We also support numerous instructional software tools. These tools range from lecture capture and delivery, to virtual desktop environments and Canvas

our learning management system. We work directly with faculty to ensure all required software is deployed in our computer labs across campus.

## Privileges and Responsibilities

Missouri S&T IT provides access to computing, networking and information resources in support of teaching, research and other official duties of the university. Access to the computing resources and facilities is a privilege, not a right. The Missouri S&T Computing and Network Facilities Acceptable Use Policy describes the ethical and legal responsibilities regarding computing resources.

Other computing policies and procedures, including the University of Missouri policies, can be found at <https://it.mst.edu/policies/>.

## Individually Owned Devices

Missouri S&T's IT department, in partnership with The S&T Store, provides recommendations for hardware and software to those wishing to purchase for personal use.

Academic discounts are available for personally-owned computers and software purchased through The S&T Store. Most software on university-owned machines is provided through licensing agreements with various vendors.

All students have access to a free copy of Office Professional for Students through Missouri S&T (Microsoft Office Suite). Contact the IT Help Desk at 573-341-4357 or visiting the IT Help Desk on the first floor of the Curtis Laws Wilson Library.

Missouri S&T faculty and staff can purchase a discounted version of Microsoft Office for their use at home through Microsoft's Home Use Program (HUP) as part the University's software licensing agreement with Microsoft. Visit the UM DoIT "My Services (<https://myservices.missouri.edu/Services/ServiceDetails.aspx?sdi=nqBZH0XoALuh1nBlSd6vJlf0ovAu86pxmhBlv5sv9us1>)" application for additional information and instructions on how to sign up.

IT recommends specific free antivirus software. In particular, Windows Defender (<http://windows.microsoft.com/en-US/windows/products/security-essentials/>) for Windows Computers.

## Connecting to the Network

Computers in campus residence halls and fraternities or sororities connect to the network through an Ethernet connection or via wireless connection. Wireless coverage currently extends to nearly 100 percent of the campus - providing great flexibility and convenience for members of the campus community.

Detailed instructions on connecting to the network, using either wired or wireless Ethernet, are available by supported operating system at: <https://it.mst.edu/services> (<https://it.mst.edu/services/>).

Virtual private network (VPN) connections are available, which allow members of the campus community to connect to the network while away from campus or traveling.

Special usage policies apply to network connections. For more information, see the policies and procedures web page at <https://it.mst.edu/policies/>. (<http://it.mst.edu/policies/>) In addition, Ethernet cards (both wired and wireless) and cables may be purchased through The S&T Store, located in the Havener Center.

## Emergency Alert System

Missouri S&T has a system in place to alert the campus community in the event of a campus-wide emergency. An email is automatically sent to every university email account, but students, faculty and staff can enter additional contact information and register to receive emergency alerts via cell phone voicemail or text message.

For more information, or to register for the Emergency Alert System, visit: <http://alert.mst.edu/>. (<https://alert.mst.edu/>)

## Getting Help

The Missouri S&T IT help desk is available to assist the students, faculty and staff of Missouri S&T in using the different computing systems on campus.

Help is available on a wide range of items, including Windows-based PCs, Macintosh systems, and Linux workstations, as well as supported software on these systems.

Members of the campus community may call 573-341-HELP (4357), stop by the IT help desk on the first floor of the Missouri S&T Library, or access the online help request system at <https://help.mst.edu>. Hours of operation are available by visiting <https://it.mst.edu/help-desk> (<https://it.mst.edu/help-desk/>).

## Internet Resources

- Campus Library – <https://library.mst.edu>
- IT Department Homepage – <https://it.mst.edu>
- IT Help Desk – <https://it.mst.edu/help-desk> (<https://it.mst.edu/help-desk/>)
- IT Services – <https://it.mst.edu/services/>
- Joe'SS (student web portal) – <https://joess.mst.edu>
- Missouri S&T campus gateway – <https://www.mst.edu>
- Online Help Request – <https://help.mst.edu>

## International Affairs

International Affairs (IA) leads Missouri S&T's efforts to promote international education and increase global awareness on campus and in the community. Serving as an umbrella for Missouri S&T's international activities, we provide services in the following areas: International Student Services, Visiting Scholars, Global Partnerships, Applied Language Institute, International Travel, and Study Abroad.

The office of international affairs (IA) coordinates international activities, administers all matters involving immigration for international students and exchange visitors, and provides advisement services to the university's international population.

The office of international affairs administers Missouri S&T's Applied Language Institute, which houses the Intensive English Program. IA is responsible for the organization of international protocol activities, promotes and monitors international linkage agreements, and administers a variety of international contracts.

Office of the Associate Provost  
International Affairs  
103 Norwood Hall  
Rolla, MO 65409-0160 USA  
573-341-6425

## International Sponsored Student Program

A full range of services for sponsored international students is provided through the office of international affairs. International students sponsored by international agencies receive special services and are assessed a sponsored student fee for each semester.

Details on the current sponsored student program can be found on the following website: <https://international.mst.edu/sponsored-student-services/>.

Southwestern Bell Cultural Center  
1207 N. Elm Street  
Rolla, Missouri 65409-0160 USA  
573-341-6015  
[iasss@mst.edu](mailto:iasss@mst.edu)

## Mandatory Health Insurance for International Students

All international students are required to purchase Missouri S&T international student health insurance as a condition of their enrollment. This includes all F-1 and J-1 visa holders. F-2 visa holders who are enrolled in classes at the intensive English program (IEP) and/or Missouri S&T are also required to purchase Missouri S&T international student health insurance. Student insurance premiums are typically charged to the student's Missouri S&T cashier's account.

In addition, the J-2 dependents of the J-1 visa holders are required by U.S. department of state immigration regulations to purchase health insurance meeting J visa requirements.

For additional information on Mandatory Health Insurance Requirements please visit the following website: <https://international.mst.edu/insurance/>.

Office of International Affairs  
Insurance Services  
104 Norwood Hall  
Rolla, MO 65409-0160 USA  
573-341-6875  
[iainsure@mst.edu](mailto:iainsure@mst.edu)

## Study Abroad Programs

The office of international affairs coordinates study abroad opportunities for Missouri S&T students. Students may choose from a variety of exchange opportunities including semester or year abroad, faculty-led short term exchange and summer abroad. Semester, year, or summer abroad programs offer opportunities to earn credit towards the student's Missouri S&T degree program.

Semester, year, and summer study abroad programs are available in approximately 50 countries. Missouri S&T offers exchange options ranging from studying courses in English at a foreign university, studying in a foreign language, or participating in a faculty-led program. Additional information, including a list of countries and universities where students may study abroad, is available at <http://studyabroad.mst.edu>.

Students eligible for financial assistance at Missouri S&T may be able to apply financial aid to study abroad. Students are encouraged to contact the student financial assistance office for details.



For additional information on Study Abroad please visit the following website: <https://studyabroad.mst.edu/>.

Office of International Affairs  
Study Abroad  
104 Norwood Hall  
Rolla, MO 65409-0160 USA  
573-341-6237  
[studyabroad@mst.edu](mailto:studyabroad@mst.edu)  
<http://studyabroad.mst.edu>

## International Travel Approvals and Travel Registrations

All university-sponsored or university-related international travel by students or faculty/staff traveling with students requires two forms of approval:

1. Risk management approval by the Provost or his/her designee
2. Approval by academic or administrative department

Information about the approval process and links to the forms are available online at <https://international.mst.edu/travelingonbehalfofmissourist/>.

In addition to the required approvals, students traveling internationally are required to register in a university approved travel registry. Missouri S&T travelers can access the travel registry at <http://globalminers.mst.edu>. Faculty and/or staff members or non-S&T affiliated travelers who are accompanying students are also required to register their travel. Faculty and/or staff members who are not traveling with students may voluntarily register their travel. The purpose of the travel registry is to provide information to travelers of resources available to them while traveling and to assist the university to quickly and easily locate university travelers during an emergency.

Missouri S&T policies operate in accordance with the CRR 210.070 Guidelines for University of Missouri Related International Programs (Section E: Guidelines for Other University Related Travel).

For additional information regarding International Travel Approvals and Travel Registration please visit the following website: <http://international.mst.edu/travelingonbehalfofst/>.

Office of International Affairs  
Insurance Services  
104 Norwood Hall  
Rolla, MO 65409-0160 USA  
573-341-6875  
[iainsure@mst.edu](mailto:iainsure@mst.edu)

## Exchange Visitor Program

The office of international affairs administers Missouri S&T's exchange visitor program for all department of state (DOS) certified visitor categories in accordance with DOS regulations and processes. Missouri S&T is currently certified to host exchange visitors in the following categories:

- Professor
- Research scholar
- Short-term scholar
- Student intern

- Non-degree seeking student
- Degree seeking student

The office of international affairs works closely with faculty members, enrollment management, graduate studies, and other campus entities on the eligibility requirements and qualifications of the prospective exchange visitor, as well as on completion of applicant documents. The office provides orientation programming to all categories of exchange visitors. The office staff coordinate with the exchange visitor faculty advisory committee and faculty exchange visitor hosts to provide DOS-mandated cultural programming and opportunities.

All exchange visitors must purchase mandatory health insurance: <https://international.mst.edu/insurance/>

For additional information regarding the Exchange Visitor Program please visit the following website: <https://international.mst.edu/visiting-scholar-services/>.

Office of International Affairs  
Exchange Visitor Program  
103 Norwood Hall  
Rolla, MO 65409-0160 USA  
573.341.4208  
[ia@mst.edu](mailto:ia@mst.edu)

## Intensive English Program (IEP)

The Intensive English Program (IEP) at Missouri University of Science and Technology provides intensive instruction in the English language for international students whose proficiency in the language is insufficient for full-time academic admission to Missouri S&T.

The mission of the IEP at Missouri S&T is to assist international students in attaining the proficiency level needed to meet language standards and promote a successful transition to academic programs. The program provides courses in English grammar, writing, reading comprehension, listening comprehension, pronunciation, and presentation at four proficiency levels.

All international students who have not satisfied S&T's language proficiency requirements are required to complete the program's assessment testing, which is comprised of four parts:

**Michigan Test of English Language Proficiency (MTELP)** A standardized test that evaluates abilities in grammar, reading comprehension, and vocabulary.

**Michigan English Language Institute College English Test - Listening (MELICET-L)** A standardized test that evaluates abilities to understand spoken English.

**Test of Writing Proficiency (TWP)** A locally developed test that evaluates abilities to write clear, well-organized English based on nationally developed guidelines.

**Oral Proficiency Evaluation (OPE)** A locally developed test that evaluates abilities to speak English clearly based on nationally developed guidelines.

Students who perform well on all tests may be approved for full-time academic course work at the university. Students who meet the requirements for the pathway program may be authorized to concurrently enroll in both academic courses at the university and English classes in the IEP. Other students are enrolled in IEP course work, and may

then complete the series of tests again at the end of the semester. Recommendations for promotion into a higher level of the IEP or for advancement into university coursework are made by the IEP's program manager based on students' course grades, and testing results.

For more information on the Intensive English Program please visit the following website: <https://ali.mst.edu/>.

Intensive English Program (IEP)  
Southwestern Bell Cultural Center  
1207 N. Elm Street  
Missouri University of Science and Technology  
Rolla, MO 65409-1140 USA  
Phone: 573-341-6351 or 573-341-6015  
Fax: 573-341-4514  
mstali@mst.edu  
<http://ali.mst.edu>

## Miner Wellness

Through health education and promotion, Miner Wellness strengthens the well-being of S&T students by reinforcing healthy habits of the majority and reducing the impact of high-risk behaviors.

Miner Wellness provides programs, presentations, and consultations on the following topics:

- Alcohol and Other Drug Harm Reduction
- Sexual Health
- Interpersonal Violence Prevention
- Sleep Health and Stress Management
- Nutrition and Fitness
- Bystander Intervention

### MINERS CARE COMMITTEE ON MENTAL WELL-BEING

The Miners Care Committee fosters a culture of mental well-being at Missouri S&T through the collaborative efforts of faculty, students, and staff. We coordinate and provide initiatives that assist students with the management of stress and encourage all members of campus to share in the responsibility of supporting student mental well-being.

### BYSTANDER INTERVENTION

STEP UP! is Missouri S&T's bystander intervention program that empowers the campus community to foster a culture of awareness, intervention, and inclusion. It helps students recognize problematic events and increases their motivation, skills, and confidence when responding to problems or concerns.

### MISSOURI S&T PREVENTION COALITION

The Missouri S&T Prevention Coalition is a network of campus and community partners who utilize S&T specific data to guide wellness initiatives. These initiatives encourage positive choices among students and reduce the impact of high-risk behavior associated with alcohol and other drugs. We collaborate closely with Partners in Prevention (PIP) and twenty other Missouri universities to guide and improve Miner Wellness programming.

### CONSULTATIONS

Miner Wellness offers one-on-one consultations for students in the areas of: nutrition, tobacco cessation, alcohol and cannabis screening, bystander intervention, and general wellness.

### PEER EDUCATION

Miner Wellness coordinates a peer education network comprised of three student groups: Joe's PEERS, Peer Wellness Educators, and STEP UP! Student Ambassadors. Through participation in the peer education program, students gain professional development and leadership experience. They also provide education and resources to their fellow S&T students to encourage safe and healthy behavior.

### MINER OASIS

The Miner Oasis was created to be a relaxing environment, off the beaten path, for students to enjoy and unwind. The Oasis is equipped with puzzles, board games, mindfulness activities, aromatherapy, crafts, fresh fruit, and free coffee and tea. The Miner Oasis is located in Norwood 201 and open Monday through Friday from 8AM to 4:30PM.

### Contact Information:

Jessica Gargus, M.ED, CHES  
Director of Miner Wellness  
201, 202, 203 Norwood Hall  
573-341-4225  
minerwellness@mst.edu  
<http://minerwellness.mst.edu>

## Missouri Score Card

Pursuant to Missouri HB 1606 (2018), information regarding the number of credit hours, program length, employment rate, wage data, and graduates employed in careers related to their program of study at Missouri University of Science and Technology can be found at the following URL: <https://scorecard.mo.gov/scorecard/>.

### To Search:

- Leave the School/Program box blank. Choose Missouri University of Science & Technology in the listing under School.
- Click Search.

## Nuclear Reactor

The Missouri S&T Nuclear Reactor is a Nuclear Regulatory Commission (NRC) licensed 200 kilowatt pool-type reactor that is used to support the engineering and science activities on campus. Using the facility, the reactor staff provides hands-on laboratory, research & development, and project opportunities. The reactor itself uses uranium fuel and is cooled by either natural convection or a 400 kilowatt forced cooling system in a pool containing approximately 30,000 gallons of water. The reactor generates a brilliant blue glow (Cerenkov radiation) when operated at higher power.

The open pool design allows access to the reactor core where experiments and samples to be irradiated can be positioned. The facility is equipped with a pneumatic sample irradiation system, a collimated neutron beam, a thermal column that provides a diffuse thermal neutron source, a gamma spectroscopy system, computer data acquisition and control systems, and an internet accessible hot cell.

The reactor is open to the greater campus community and offers an active (operations) licensure program for interested students and others. The facility hosts numerous projects that actively engage students of various backgrounds; some recent projects include activities in:

- applied robotics
- applied biometrics

- photolytically-induced material development
- radiation tolerance of electronic chips
- instrumentation and sensors
- convective heat transfer and multiphase flows

We encourage you to contact the facility for additional information.

## Oak Ridge Associated Universities (ORAU)

Since 1981, students and faculty of the Missouri University of Science and Technology have benefited from its membership in Oak Ridge Associated Universities (ORAU). ORAU is a consortium of more than 100 major Ph.D. granting institutions and a contractor for the U.S. Department of Energy (DOE) located in Oak Ridge, Tennessee. ORAU works with its member institutions to help their students and faculty gain access to federal research facilities throughout the country; to keep its members informed about opportunity for fellowship, scholarship, and research appointments; and to organize research alliances among its members.

Through the Oak Ridge Institute for Science and Education (ORISE), the DOE facility that ORAU operates, undergraduates, graduates, postgraduates, as well as faculty enjoy access to a multitude of opportunities for study and research. Students can participate in programs covering a wide variety of disciplines including business, earth sciences, epidemiology, engineering, physics, geological sciences, pharmacology, ocean sciences, biomedical sciences, nuclear chemistry, and mathematics. Appointment and program lengths range from one month to four years. Many of these programs are especially designed to increase the number of under-represented minority students pursuing degrees in science- and engineering- related disciplines. A comprehensive listing of these programs and other opportunities, their disciplines, and details on locations and benefits can be found at <http://www.orau.gov/> or by calling either of the contacts below.

ORAU's office of partnership development seeks opportunities for partnerships and alliances among ORAU's members, private industry, and major federal facilities. Activities include faculty development programs, such as the Ralph E. Powe Junior Faculty Enhancement Awards, the Visiting Industrial Scholars Program, consortium research funding initiatives, faculty research, and support programs as well as services to chief research officers.

For more information about ORAU and its programs, contact:

Dr. Constantinos Tsatsoulis, Vice Chancellor for Research and Dean of Graduate Studies, ORAU counselor for Missouri S&T 573-341-4141

Rachel Lokitz, ORAU corporate secretary  
865-576-3306 or visit <http://www.orau.org>

## Office of Graduate Studies

The mission of the office of graduate studies is to administer student-centric services from inquiry through graduation and provide campus leadership for excellence in graduate education. Our mission is four-fold in support of our students, faculty, and staff.

1. Recruit and retain high quality graduate students in collaboration with the other campus units by providing excellent graduate education opportunities and advocating student issues to improve the quality of student life.

2. Provide a relevant student learning environment to foster innovation, creativity, and scholarship so that students can aim high to reach their true potential.
3. Provide student-centric services to ensure students graduate in a timely fashion.
4. Provide campus leadership to promote excellence in graduate education by actively engaging student leaders, graduate faculty, and staff.

## Office of the Registrar

### Mission Statement

The primary mission of the office of the registrar is to ensure the accuracy, integrity, and security of the academic records of the Missouri University of Science and Technology. In addition, the office will strive to provide quality service to students, alumni, faculty, staff, and other constituents of the university. To this end, the office will attempt to utilize available technology to deliver services and information in an efficient manner. Further, the office will seek to interpret and apply the academic policies and regulations of the university for the benefit of the institution and its constituents.

### Confidentiality Policy: The Family Educational Rights and Privacy Act of 1974 (FERPA)

These statements are set forth as guidelines and procedures to implement the University of Missouri policy on student records developed from the Family Educational Rights of Privacy Act 1974 (FERPA).

The Missouri University of Science and Technology as charged in the act will annually inform its eligible students by including in the academic regulations and the general catalog the following information:

1. "Educational records" are those records, files, documents, and other materials which contain information directly related to a student and are maintained by the university. Those records made available under FERPA are student financial aid, the student's cumulative advisement file, student health records, disciplinary record, the admissions file, and the academic record. The Missouri University of Science and Technology "educational records" do not include:
  - A. Records of instructional, supervisory, and administrative personnel and educational personnel ancillary thereof which are in the sole possession of the maker thereof and which are not accessible or revealed to any other person except a substitute.
  - B. The records and documents of the University of Missouri police department that are maintained solely for law enforcement purposes and are not available to persons other than law enforcement officials of the same jurisdiction.
  - C. In the case of persons who are employed by the university but are not in attendance at the university, records made and maintained in the normal course of business which relate exclusively to such person and person's capacity as an employee where the records are not available for any other purpose.
  - D. All records on any university students which are created and maintained by a physician, psychiatrist, psychologist, or other recognized professional or paraprofessional acting in his or her professional or paraprofessional capacity, or assisting in that capacity, and which are created, maintained, or used only in connection with the provision of treatment to the student, and

- are not available to anyone other than persons providing such treatment, provided, however, that such records can be personally reviewed by a physician or other appropriate professional of the student's choice.
2. The Missouri University of Science and Technology recognizes "directory information" to be the student's name, e-mail address, address, telephone listing (including local and permanent address), major field of study, participation in officially recognized activities and sports, dates of attendance, degrees and awards received, the most recent previous educational agency or institution attended by a student, student level, and full- or part-time status. All students must inform the Registrar's Office before the end of the two-week period following the first day of classes for fall and spring semesters, and before the end of the one-week period following the first day of classes for summer session, that this information should not be released without the student's prior consent. The information listed above will become directory information if the student does not notify the Registrar's Office as specified.
  3. Missouri University of Science and Technology students have access to the educational records identified in paragraph one above. In accordance with Pub. L. 93-380, as amended, the Missouri University of Science and Technology will not make available to students the following material:
    - A. Financial records of the parents of students or any information contained therein.
    - B. Confidential letters and statements of recommendation which were placed in the education records prior to January 1, 1975, if such letters or statements are not used for the purpose other than those for which they were specifically intended.
    - C. Confidential recommendations respecting admission to the university, application for employment, and receipt of an honor or honorary recognition, where the student has signed a waiver of the student's rights of access as provided in 6.0404 the university policy on student records.
  4. The director of financial aid, the appropriate academic department chair, the director of the student health service, the vice chancellor for student affairs, the director of admissions, and the registrar are the officials responsible for the maintenance of each type of record listed in paragraph one.
  5. Any student may, upon request, review his or her records and if inaccurate information is included, may request the expunging of such information from his or her file. Such inaccurate information will then be expunged upon authorization of the official responsible for the file.
  6. Students desiring to challenge the content of their record may request an opportunity for a hearing to challenge the content of his or her educational record in order to ensure that the record is not inaccurate, misleading or otherwise in violation of the privacy or other rights of the student, and to provide an opportunity for the correction or deletion of any such inaccurate, misleading, or otherwise inappropriate data contained therein and to insert into such records a written explanation respecting the content of such records.
  7. The university official charged with custody of the records will attempt to settle informally any disputes with any student regarding the content of the university's educational records through informal meeting and discussions with the student.
  8. Upon request of the student or the university official charged with custody of the records of the student, a formal hearing shall be conducted, as follows:
    - A. The request for a hearing shall be submitted in writing to the campus chancellor who will appoint a hearing officer of a hearing committee to conduct the hearing.
    - B. The hearing shall be conducted and decided within a reasonable period of time following the request for the hearing. The parties shall be entitled to ten days prior written notice of the item and place of the hearing.
    - C. The hearing shall be conducted and the decision rendered by an appointed hearing official or officials who shall not have a direct interest in the outcome of the hearing.
    - D. The decision shall be rendered in writing within a reasonable period of time after the conclusion of the hearing.
    - E. Either part may appeal the decision of the hearing official or officials to the campus chancellor. Appeal from the chancellor's decision is to the president of the Board of Curators.
  9. The Missouri University of Science and Technology may permit access to or release the educational records without the written consent to a school official with legitimate educational interest. A school official is determined to have legitimate educational interest if the information requested is necessary for that official to (a) perform appropriate tasks that are specified in his or her position or by a contract agreement; (b) perform a task related to a student's education; (c) perform a task related to the discipline of a student; (d) provide a service or benefit relating to the student or student's family, such as health care, counseling, job placement or financial aid.
  10. If any material or document in the educational record of a student includes information on more than one student, they may inspect and review only such part of such material or document as relates to him or her or to be informed of the specific information contained in such part of such material.
  11. Students desiring reproduction of copies of educational records will be charged \$.10 per page. Official copies of transcripts are \$10.00 per copy for currently enrolled students and alumni.

## University Communications to Students

Each student, once initially admitted, will be issued a Missouri S&T e-mail account with an address on the mst.edu domain. This is the account used for official university business and official university communications to students. Students are expected to regularly check their Missouri S&T e-mail account for university communications and are responsible for communications sent to this account. Therefore, communications sent to this account will be considered to have fulfilled any university obligation for notification.

## Application for Graduation

Students planning on graduating must do the following:

- Check application deadlines for semester in which you are applying for graduation
- Fill out the online application for graduation form found in Joe'sS and submit through the online process

A \$75 graduation fee is assessed to all students who have applied as a candidate for graduation. This fee will be charged to the student account after submitting an application for graduation.

A \$25 certificate graduation fee is assessed to all students who have applied as a candidate for completion. This fee will be charged to the student account after submitting a certificate application for completion.

## Schedule of Classes

The most current information regarding the schedule of classes is located in Joe'SS at <https://joess.mst.edu> (<https://joess.mst.edu/>).

## Course Information

The number in parentheses following the name of the course indicates the number of credit hours given for successfully completing the course. It also reflects the section type; for example, (LEC 3.0) designates a lecture course of three hours credit; (LAB 1.0) designates a laboratory course of one-hour credit, (RSD 2.0) designates a recitation, seminar, discussion of two hours credit, and (IND 0.0-15.0) designates independent study or research with variable hours. A lecture credit hour is usually the credit granted for satisfactorily passing a course of approximately 15 classroom hours. A laboratory course of one-hour credit would normally meet three classroom hours per week for 15 weeks.

Three credit hour courses normally meet 50 minutes three times per week, or 75 minutes twice a week, for 15 weeks. The time in class is the same in each case. If you have two classes in succession, there should be at least ten minutes between classes. Classes meeting Monday-Wednesday-Friday will normally begin on the hour. Classes meeting Tuesday-Thursday will normally alternate between the hour and half hour, beginning at 8:00 a.m.

Students must have completed the stated prerequisite(s) for the course for admission to the course or obtain the 'consent of the instructor' of the course.

## Course Numbers

This section has been prepared to give you a listing and description of the approved courses at the Missouri University of Science and Technology. Courses listed are those approved at the time this publication went to press. Changes are made at regular intervals. Electronic catalog descriptions, which are updated during the academic year, are available through Joe'SS at <http://registrar.mst.edu> (<http://registrar.mst.edu/>). This will enable you to keep abreast of new course additions. For current information on when courses are available, consult class offerings available through Joe'SS.

Number	Description
1000-1999	Freshmen-level courses
2000-2999	Sophomore-level courses
3000-3999	Junior-level courses
4000-4999	Senior-level courses
5000-5999	Entry and mid-level graduate courses (undergraduate enrollment allowed)
6000-6999	Advanced graduate courses

## Absence from Class

Work missed due to absence from class must be made up to the satisfaction of the instructor concerned. Excessive absences from class may result in the student being dropped from the course at the request of his or her instructor.

## Missouri S&T Grade Reports on the Web

Students may obtain their grades on the web through Joe'SS. Students who desire a paper copy of their grade report should contact the registrar's office.

## Certification of Enrollment Status

Certifications of enrollment status should be requested through Joe'SS at <https://joess.mst.edu> (<https://joess.mst.edu/>). Certification of full-time or half-time status is based on the number of credit hours for which the student is enrolled and includes courses in which the student is enrolled as a hearer, with one exception. Hearer courses are not included for international student status, as defined by SEVIS.

For graduate students, full-time is based on at least 9 credit hours; half-time is at least four credit hours during the regular fall and spring term. For the summer term full-time is three credit hours and half-time is at least two credit hours.

## Grading System

The following system of grades is used:

Grade	Grade Points Per Credit Hour
A-Excellent	4
B-Superior	3
C-Medium	2
F-Failure	0
I-Incomplete	
S-Satisfactory	Indicates credit has been earned for the course scheduled
U-Unsatisfactory	Indicates credit has not been earned for the course scheduled
DL-Delayed	Permissible for ongoing research
Y	No grade available

Grades of "S" and "U" are used for research (6099), internship (5085/6085) and continuous registration (6050). Grades of S and U are also permitted for special problems (3000/4000/5000/6000) and seminar (3010/4010/5010/6010).

The purpose of the "I" grade is to allow a student to complete a course when, due to illness or unavoidable absence within the last four weeks (three weeks of classes plus finals weeks) of a fall or spring semester or within the last week and a half plus the final exam period of an eight-week summer session, he/she would otherwise be unable to do so. The intent is to provide a means for completing a course without having to retake the entire subject for lack of fulfillment of one or two requirements of the course.

Graduate students cannot take courses with a pass/fail grading option. "D" grades are not permitted for graduate students.

For a complete explanation of grades and grading options refer to the Student Academic Regulations handbook at: <http://registrar.mst.edu/academicregs/index.html>. (<http://registrar.mst.edu/academicregs/>)

## S&T Police Department

### Parking

All student-operated vehicles should have either a valid campus parking permit or student registration decal affixed properly to the vehicle. Missouri S&T Parking, Security and Traffic Safety Regulations, as adopted by the Parking, Security and Traffic Safety Committee and approved by the chancellor, provide for the payment of established fees for parking privileges and set fees for violation of those regulations. The university police department has the responsibility of enforcing parking regulations at Missouri S&T.

The size of the student body, faculty, and staff, coupled with the fact that a large number of students live off-campus, leads to a relatively large number of motor vehicles on and near the campus. This traffic load, in turn, complicates parking for the campus citizen and creates a hazard for vehicles and pedestrians. The committee has prescribed the rules governing the classification and use of parking lots, the qualifications for parking on those lots, and the rules for application, issuance, and use of parking permits.

Specific information on current regulations and other details pertaining to parking can be obtained at the University Police Department, G-10 Campus Support Facility, 573-341-4303. The regulations may also be found at: <http://police.mst.edu/parking/>.

### Missouri S&T Parking: Rules in Capsule Form

- All parking on campus requires either a purchased permit or payment at a meter. Decals (permit and registration stickers) must be affixed to the outside of the rear window or bumper on the driver's side of the vehicle. Temporary tags will need to be hung on the rear-view mirror.
- All vehicles shall be parked **HEADING** into the parking spaces. (Do not back into or pull through the space.)
- A visitor is anyone **OTHER THAN** an employee, student or member of their family.
- Regulations pertaining to area permits and metered parking are enforced **YEAR ROUND** from 7:30 a.m. to 4:30 p.m. except on Saturdays, Sundays and official university holidays. Other regulations are enforced at all times.
- Permit and metered parking at Thomas Jefferson Residence Hall and the Multi-Purpose Building shall be enforced 24 hours a day 7 days a week.
- Employees and students lending their vehicle to a visitor will be responsible for any violations occurring on campus.
- Parking permit owners shall park only in the area to which the purchased permit allows access.
- Employees and students without parking permits shall use only metered spaces.
- Specially marked disabled parking, driveways, yellow curbs and zones, spaces marked for 24 hour enforcement, fire lanes, vehicle types and areas not designated as a parking area, etc., shall be enforced 24 hours a day seven days a week.
- University driveways, yellow curbs and zones, and any other area not specifically designated as a parking area shall not be used at any time.

- The Director of University Police, with the concurrence of the Parking Committee Chair, shall have the authority to suspend all or part of the parking regulations for specific periods of time.

The full and complete set of Missouri S&T Parking Rules and Regulations can be found on our website, <http://police.mst.edu/parking/>.

### Lost and Found

The university police department is the central "lost and found" repository for the campus. Any lost and found items should be turned into the university police for reclamation purposes. If an item is lost, information should be filled out with university police, 573-341-4300, or can be reported by accessing: <http://police.mst.edu/programs/lostitems> (<http://police.mst.edu/programs/lostitems/>) in case the item is turned in at a later date.

### Campus Security

#### Missouri State Uniform Crime Reporting (UCR) Statistics

Every law enforcement agency in the state is required to report crime data monthly to the Missouri State Highway Patrol (MSHP). MSHP creates and maintains computer files of the Missouri data and supplies information not only to the Federal Bureau of Investigations (FBI) for use in national crime statistics, but also to local agencies and organizations. To access crime data for the Missouri S&T police department submitted to the MSHP visit the MSHP Statistical Analysis Center: [http://www.msph.dps.missouri.gov/MSHPWeb/SAC/data\\_and\\_statistics\\_ucr.html](http://www.msph.dps.missouri.gov/MSHPWeb/SAC/data_and_statistics_ucr.html).

#### Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act (CLERY)

As required by the U.S. Department of Education, the CLERY Act requires higher education institutions to make public certain crime data. Review the annual CLERY report submitted by the Missouri S&T police department online: <http://police.mst.edu/info/clery/>. A paper copy of the report can be requested by contacting the Missouri S&T police department at 573-341-4300 or by responding to the department which is located in G-10 Campus Support Facility.

#### Daily Crime Report

The CLERY Act also requires that crime information be made available to the public within two working days. Review the Daily Crime Report in the lobby of the Missouri S&T police department located in G-10 Campus Support Facility or at <http://police.mst.edu/info/crimestatistics/crime-report/>.

### University Police

The mission of the Missouri S&T police department is to support the academic and campus community in fulfilling its commitment to teaching, research, and service. The functions performed by the Missouri S&T police department include many services offered by a small municipal police agency, as well as certain service functions unique to the university setting. The Missouri S&T police department is comprised of state commissioned police officers, security guards, parking enforcement staff, administrative staff, and student employees (campus service officers). Missouri S&T police officers are empowered under Chapter 172.350 of the Missouri Revised Statutes. As such the police officers are commissioned and armed. Additionally all Missouri S&T police officers possess Rolla City Police commissions as well. The

S&T university police are also fully accredited through the International Association of Campus Law Enforcement Administrators (IACLEA).

Police officers patrol on foot, bicycle and by vehicle all properties owned by the Missouri University of Science and Technology 24 hours-a-day and seven days-a-week. The security guards perform additional security checks on main campus during evening and night hours. In addition to the full-time staff, the department employs students on a part-time basis, who serve as campus service officers (CSOs). Missouri S&T police department also has a Reserve Police Officer Program where part-time, fully sworn, police officers are used on an as-needed basis. Please visit the university police department's webpage to see all of the various services offered by the university police <http://police.mst.edu>.

Duties of the Missouri S&T police department include, but are not limited to preventative patrols, the investigation of crimes, crime prevention through active campus involvement, service to students and others in emergencies, special event coverage, overseeing parking lot operations, and the enforcement of state laws, city ordinances, and university rules and regulations. The university police department monitor several security cameras located throughout campus via a 24/7 operations desk located at the university police department. The university police are dispatched via the Rolla area 911 call center located within the Rolla police department. The camera views for the campus are shared with the call center. The university police can be reached at any time via 911 or for non-emergency situations, 573-341-4300.

## Reporting Crimes at Missouri S&T

A log of all reported crimes is posted at the Missouri S&T police department (G10 Campus Support Facility) and on our website <http://police.mst.edu/reporting/crimes/>, under crime statistics to meet Clery Act requirements.

All crime victims are highly encouraged to report incidents to the Missouri S&T police department regardless of how seemingly insignificant the crime. Missouri S&T policy requires employees to promptly report all criminal acts occurring on campus. To report a crime, the victim or witness need only call the Missouri S&T police department via 911 or 573-341-4300. A police officer will meet with the person to gather information and prepare an official report. You may wish to report an incident to have the alleged offender apprehended and/or for the protection of yourself or others. If this is the case, successful apprehension and/or prosecution of the offender depends greatly on the rapid and accurate report of the crime. Information about the incident can assist law enforcement authorities in providing and improving prevention strategies for the protection of the victim and others in the community.

If you wish to report an incident without seeking disciplinary or legal actions, please contact the Missouri S&T counseling and disability support department, the equity and title IX department, the dean of students and student affairs department, the residential life department, the campus human resources department or any campus security authority \*\* for assistance.

Additional contact and resource information for reporting a crime is available by calling the university police department at 573/341-4300 or online via <https://police.mst.edu/reporting/crimes/>, <http://titleix.mst.edu/reporting/> (<http://titleix.mst.edu/reporting/>), and <http://dos.mst.edu/studentcompliantprocess/> (<http://dos.mst.edu/studentcompliantprocess/>).

\*\*The campus security authority is an official of an institution who has significant responsibility for student and campus activities, as well as employees who control or monitor access to various locations on campus.

## Security of Campus

Accountability of the security of campus facilities originates with the department chair. Areas of responsibility include, but are not limited to, both interior and exterior entryways, exits, and windows, and items of value within the department. Areas not under a specific department shall be under the responsibility of the next higher level within the division.

The department chair is ultimately answerable for security problems existing within his/her area of control, but can designate a dependable and reliable individual(s) areas of security responsibility.

A particularly sensitive area in building access control is the issuance of keys by departments to faculty, staff, and students. Department key issuance and control shall comply with guidelines set forth in BPM-404 Keys to University Buildings: [http://www.umsystem.edu/ums/rules/bpm/bpm400/manual\\_404](http://www.umsystem.edu/ums/rules/bpm/bpm400/manual_404) ([http://www.umsystem.edu/ums/rules/bpm/bpm400/manual\\_404/](http://www.umsystem.edu/ums/rules/bpm/bpm400/manual_404/)).

Buildings shall be secured during the evening hours at the earliest reasonable time. Any facility open for an extended period after normal operating hours for that building shall require a permit to be open for the hours specified on the permit.

During the academic year in which residence halls are open, those halls shall be secured during the evening hours according to housing department regulations. Faculty, staff, and students are encouraged to prevent access by unauthorized personnel, in both residence halls and other campus buildings, by verifying any door entered or exited has closed and locked.

Maintenance of campus facilities involving security problem areas, such as broken locks, windows, door, etc., shall involve reporting the security problem as soon as possible to the physical facilities department, who shall rectify the security breach within a timely manner.

In the event of a campus emergency, the university police department will notify the campus community via a RAVE mass notification message. The message will note the situation, give basic direction, and it updates until the situation is resolved or stabilized. Messages will be sent via text, email, phone, and received on desktops on campus or in campus housing. There may be situations when messages will only be sent via text and email (severe thunderstorm warning). Campus visitors can sign up to receive emergency mass notification messages by texting MINEREVENT to 78015.

## RAVE Guardian

Missouri S&T University purchased an add-on phone app for the campus community. The app is named Rave Guardian and is available for free at the app store for anyone who has a Missouri S&T email address. The app has several different valuable components including a safety timer, a method to text message the university police, an icon to reach the university police with the touch of a button, and the ability to call the 911 call center with the touch of a button. For further information on the Rave Guardian app please visit the website: <http://ravemobilesafety.com> or contact the university police department via email [police@mst.edu](mailto:police@mst.edu) or via phone 573-341-4300.

## Alcohol/Illegal Drugs Policies:

### Alcoholic Beverages

The use or possession of any alcoholic beverage is prohibited on all university property, except in the chancellors' residence, and the sale, use, or possession may, by appropriate university approval be allowed in approved university alumni centers or faculty clubs, and for single events and reoccurring similar events in designated conference, meeting, or dining facilities provided by university food services, subject to all legal requirements. Alcohol may also be allowed during tailgate activities (pursuant to legal requirements) in the parking lot of Gale Bullman Multipurpose Center, in conjunction with a recognized university athletic event. Further information pertaining to alcoholic beverages can be obtained from <http://chancellor.mst.edu/media/administrative/chancellor/documents/policy/I-90.pdf>.

### Illegal Drugs

University of Missouri regulations prohibit the unlawful possession, use, distribution, and sale of alcohol and illicit drugs by university students and employees on university-owned property and at university or supervised activities. Local, state, and federal laws also prohibit the unlawful possession, use, distribution, and sale of alcohol and illicit drugs. Violation of the University of Missouri regulations and federal and state laws may result in arrest and could also result in disciplinary action up to and including expulsion for students and discharge for employees.

A variety of resources exist for drug and/or alcohol counseling, treatment, or rehabilitation program. For detailed information concerning university and community resources, students and employees may contact the Substance Abuse Prevention Program, 107 Norwood Hall, 573-341-4292. Confidential consultation, assessment, short term counseling, and referral services are available free of charge to faculty, staff, and students. A variety of prevention of education programs are also offered.

## Victim of Sexual Assault Information

The following information is provided to assist a person who has been the victim of a sexual assault.

### Emergency Medical Examination/Evidence Collection

Receiving medical care immediately following a rape, attempted rape, or sexual assault is extremely important for your well-being. It is essential that you obtain:

- Emergency medical exam if you are injured.
- A general medical exam to ensure that you haven't obtained injuries that you are unaware of or unable to determine.
- A medical/legal examination for the collection of evidence if you think there is any possibility you will want to prosecute the offender. The exam must be conducted within 48 hours of the assault and you must NOT clean up before the exam to avoid loss or contamination of evidence.
- Testing for sexually transmitted diseases. AIDS, and possible pregnancy (as part of follow-up treatment).

For medical emergencies, call 911 to have an ambulance dispatched.

Other sources of medical information for victims include Missouri S&T student health services (available during business hours).

## Emotional Support

The need for emotional support and assistance after a rape, attempted rape, or sexual assault is great. In the aftermath of such a violation and loss of control, it may be difficult to consider what steps to take.

Contact a close friend or family member to talk with and assist in making decisions. Contact the Missouri S&T counseling center whose services are strictly confidential and contacting this support service does not obligate you to take any further action.

## Reporting of Incident

You may wish to report the assault in order to have the alleged offender apprehended and/or for the protection of self or others. If this is the case, successful apprehension and or prosecution of the offender depends greatly on a rapid and accurate report of the crime. Information about the assault can assist law enforcement authorities in providing and improving prevention strategies for the protection of the victim and others in the community.

You have the option of making a report for the purpose of assisting the police in protecting the community without obligation to participate in the prosecution. While the actual prosecution of the offender is pursued by the Phelps County prosecutor (not by the victim), prosecution is unlikely to occur without the consent and assistance of the victim. You have the right to choose not to contact the Missouri S&T police, but you are strongly encouraged to report the assault to the police department.

## Anonymous or Third Party Reporting

Even if you may not want to prosecute the offender to have it known you were the victim of an assault, you can choose to report the assault anonymously. Or somebody who you have told about the assault can report it. This type of reporting will provide the department with general information that may be useful in preventing additional assaults on campus. To make an anonymous report, call the police department and request to speak with an officer.

## Disciplinary Actions

Whether or not you choose to report the assault to law enforcement or participate in criminal prosecution, you may decide to take action through the campus judicial system. If you were assaulted by another Missouri S&T student, on or off-campus, the accused may be charged under the University of Missouri Standard of Conduct. The judicial officer at Missouri S&T is available to discuss campus judicial procedures. While the judicial officer may investigate the complaint and impose appropriate discipline with or without the victim's consent, discussing a matter of sexual assault with her/him does not compel the victim to participate actively in pursuing disciplinary charges. The judicial officer's phone number is 573-341-4292.

## Contact with Offender

In situations where the accused and the accuser may be in close contact with each other because of class schedules and/or living arrangements, adjustments to housing or class schedules may be made. The director of residential life has the authority to give the accuser and/or accused the option of changing living arrangements. If the accuser and the accused refuse to change living arrangements, the director has the authority to change the living arrangements of either person. The judicial officer shall give the parties the option of changing class schedules to avoid contact. However, change of class schedules cannot be required until after disciplinary proceedings have concluded.



## Student Disability Services

The mission of student disability services is to assist in creating an inclusive and accessible university community where students with disabilities have an equal opportunity to fully participate in all aspects of the educational environment. We cooperate through partnerships with students, faculty, and staff to promote students' independence and to ensure recognition of their abilities.

Missouri University of Science and Technology (S&T) strives to assure that no qualified person with a disability shall, solely by reason of the disability, be denied access to, participation in, or the benefits of any program or activity operated by the university. Each such qualified person shall receive reasonable accommodations to provide equally effective access to educational opportunities, programs, and activities in the most integrated setting appropriate unless provision of such reasonable accommodation would constitute an undue hardship on the university or would substantially alter essential elements of the academic program or course of study or would otherwise compromise academic standards.

In compliance with federal and state laws, S&T is intentional in efforts to be consistent with Section 504 of the Rehabilitation Act of 1973, which states that no recipient of federal financial assistance may discriminate against qualified individuals with disabilities solely by reasons of disability. This policy is also intended to be consistent with the Americans with Disabilities Act of 1990 and the Missouri Human Rights Act.

If you are a student with a disability and would like more information regarding the provision of services through the office of student disability services, please feel free to contact us to schedule a personal, confidential appointment.

### Contact Information

G-10 Norwood Hall  
<http://dss.mst.edu>  
 Email: [dss@mst.edu](mailto:dss@mst.edu)  
 Phone: 573-341-6655  
 Fax: 573-341-4172

## Student Diversity Initiatives

The mission of the SDI office is to foster diversity and inclusion in the Missouri S&T community by providing a welcoming climate for all students. The department aims to support underrepresented, first generation, and low income students from all walks of life through programming to foster cultural competency, persistence/retention, sense of belonging and community.

Through programs and partnerships, student diversity initiatives supports diversity-related programming and promotes awareness about female and multicultural related issues; first generation and low-income student support; SDI helps foster an academic and professional environment that supports the students of Missouri S&T and strengthens the campus community.

For more information about our peer mentoring program, cultural programming, closets for clothes, commuter's commodities, multicultural student organizations, or diversity and inclusion training visit our website at <https://sdi.mst.edu/>. You may contact us directly at 573-341-7286 or via e-mail at [sdi@mst.edu](mailto:sdi@mst.edu). Student Diversity Initiatives, 605 W. 11<sup>th</sup> Street.

## Student Health Services

The goal of Missouri S&T Student Health Services is to provide for healthy students and a healthy campus population.

Student Health offers a wide range of primary health care for currently enrolled students at Missouri S&T. Multiple providers are available to deliver care for acute illness and injury. The Student Health fee covers visits with the providers, but some procedures, labs and medications may require a small fee. It is highly recommended that all students have some form of health insurance to cover for services not provided at Student Health. An Aetna group policy is available and information on this plan may be obtained at the Cashier's Office or the Student Health Complex.

There are certain requirements that need to be met before you can complete enrollment and move onto campus. Failure to meet these requirements will result in a hold on your registration process.

To submit your information, please follow the instructions on the Student Health website <http://studenthealth.mst.edu/>.

At a minimum, students must submit records including:

- **Two Measles, Mumps, Rubella Vaccines (MMR).** The first one must be done after age 12 months; the second at least 30 days later.
- **One Meningitis Vaccine,** given after age 16. Missouri Senate Bill 754 states, "each student attending a public institution of higher education who lives in on-campus housing **must receive the meningococcal vaccine** unless he or she has a medical or religious exemption". Vaccination strongly recommended for all university students. You will not be allowed to move into campus housing if we have not received your meningitis immunization documentation. More information about the meningitis vaccine and disease can be found on the Student Health Website
- **Tuberculosis Screening Form for New Students.** This form must be completed by all students. Student Health staff will review and contact you if further testing is necessary.

For more information contact:

Student Health Services  
 910 W. 10th St.  
 Rolla, MO 65409  
 573-341-4284  
[mstshs@mst.edu](mailto:mstshs@mst.edu)

## Student Involvement

Student Involvement encourages active engagement in our community in means which complement classroom learning, <http://involvement.mst.edu/>.

There are over 200 academic, honorary, professional, intercultural, media, programming, governing, sport, faith based, service, fraternity/sorority and design teams on campus. For more information about any recognized organization, or how to get involved on campus, contact the department of student involvement at 573-341-6771 or <http://involvement.mst.edu/>.

## Volunteerism and Service

At Missouri S&T, we realize that our impact goes far beyond our campus. As a result, the office of student involvement is committed to contributing to the betterment of our local, surrounding, and global communities. We

do this by offering students a variety of opportunities to become actively engaged through service, all of which is possible due to the mutually beneficial partnership that exists between community organizations and the University. Annual events such as the Civic Engagement Fair, Martin Luther King Day of Service, Gonzo Giveback, Alternative Weekend Breaks, and the Miner Challenge Alternative Spring Break program are some of the volunteerism highlights of the academic year. Learn how to get involved in volunteer activities by joining our listserv at <http://involvement.mst.edu/volunteer> (<http://involvement.mst.edu/volunteer/>) or by watching campus announcements for opportunities scheduled throughout the year. For more information on how you can get involved in volunteerism and service, please contact the Department of Student Involvement, 218 Havener Center, at 573-341-6771 or [involvement@mst.edu](mailto:involvement@mst.edu).

transferor is a member of the uniformed service who is serving on active duty.

For more information contact the VA representative at:

Office of the Registrar  
103 Parker Hall, 300 W. 13th St.  
Rolla, MO 65409-0930  
573-341-4181  
[registrar@mst.edu](mailto:registrar@mst.edu)

## Veteran Affairs

### Veteran Access, Choice and Accountability Act of 2014, Section 702

The university is compliant with the requirements of PL 113-146 the Veteran Access, Choice and Accountability Act of 2014, Section 702. Section 702 targets educational assistance through ensuring in-state tuition/in-district rates to uniformed services veterans and their qualified dependents covered under this Section.

These new requirements will ensure that our Nation's recently discharged Veterans, and their eligible family members, will not have to bear the cost of out-of-state charges while using their well-deserved education benefits.

The following individuals shall be charged the in-state/in-district rate, or otherwise considered a resident, for tuition purposes:

- A veteran using educational assistance under either chapter 30 (Montgomery G.I. Bill – Active Duty Program), chapter 31 (Vocational Rehabilitation and Employment), or chapter 33 (Post-9/11 G.I. Bill), of title 38, United States Code, who lives in the state of Missouri while attending a school located in the state of Missouri (regardless of his/her formal state of residence) and enrolls in the school within three years of discharge from a period of active duty service of 90 days or more.
- Anyone using transferred Post-9/11 GI Bill benefits (38 U.S.C. § 3319) who lives in the state of Missouri while attending a school located in the state of Missouri (regardless of his/her formal state of residence) and enrolls in the school within three years of the transferor's discharge from a period of active duty service of 90 days or more.
- Anyone described above while he or she remains continuously enrolled (other than during regularly scheduled breaks between courses, semesters, or terms) at the same school. The person so described must have enrolled in the school prior to the expiration of the three year period following discharge or release as described above and must be using educational benefits under either chapter 30 or chapter 33, of title 38, United States Code.
- Anyone using benefits under the Marine Gunnery Sergeant John David Fry Scholarship (38 U.S.C. & 3311(b)(9)) who lives in Missouri while attending a school located in Missouri (regardless of his/her formal State of residence).
- Anyone using transferred Post-9/11 G.I. Bill benefits (38 U.S.C. & 3319) who lives in Missouri while attending a school located in Missouri (regardless of his/her formal state of residence) and the

# ADMISSIONS AND ACADEMIC PROGRAM PROCEDURES

## Admission to Graduate Study

Any person who holds a bachelor's degree, a master's degree, or any equivalent degree from a college of good standing and who wishes to enroll as a graduate student at Missouri S&T must submit all required application materials to admissions. Required materials include an on-line application, an official transcript sent from all undergraduate and any graduate institutions, standardized test scores (GRE or GMAT) if required by your academic program and non-refundable application fee of \$55 for U.S. citizens and permanent residents or \$75 for international applicants, payable to Missouri S&T. Other application materials may be required by individual programs, so please refer to the department's website or entry in the Areas of Study section of this catalog to find out the specific admission requirements for your prospective degree program. All graduate school admissions must be approved by the chair or designate of the appropriate department, as well as the dean of graduate studies.

## Application Deadlines for U.S. Students

Application materials should be received by the Missouri S&T office of admissions by the following dates:

- Fall semester – July 15
- Spring semester – December 15
- Summer session – May 1

## International Student Admission

Students from outside the United States who wish to enroll at Missouri S&T are required to submit all application materials required by their prospective department, as well as to demonstrate a command of English sufficient to pursue graduate work at Missouri S&T. International students for whom English is a second language, or whose schooling has been conducted in another language, must demonstrate sufficient command of English to successfully pursue work at Missouri University of Science and Technology by doing one of the following:

### I. Take the Test of English as a Foreign Language (TOEFL).

The campus minimum for TOEFL scores is 79 (internet-based scoring). Departmental minimum acceptable scores are listed on the office of graduate studies' website or entry in the areas of study sections of this catalog.

Students may obtain TOEFL information from:

Test of English as a Foreign Language  
Educational Testing Service  
Box 899  
Princeton, NJ 08540 USA  
<http://www.ets.org/toefl> (<http://www.ets.org/toefl/>)

The TOEFL Bulletin of Information and registration form may also be obtained in a number of cities outside the United States, and are often available at American embassies and consulates, Offices of the United States Information Service (USIS), United States educational commissions and foundations abroad, and binational centers.

Students seeking Taiwanese editions of the TOEFL should apply to:

Language Center  
2-1 Hsuchow Road

Taipei, Taiwan

TOEFL scores should be sent directly to Missouri S&T, using school code 6876.

### II. Take the International English Language Testing System (IELTS) exam.

The minimum acceptable overall band score on the IELTS exam is 6.5 for campus. Departmental minimums are listed on each department's website or entry in the areas of study sections of this catalog.

Students may obtain test information from:

IELTS Administration  
7900 W. Division  
River Forest, IL 60305  
<http://www.ielts.org>

### III. Take the Pearson Test of English (PTE) exam.

The minimum acceptable overall band score on the Pearson Test of English (PTE) exam is 53 for campus. Departmental minimums are listed on each department's website or entry in the areas of study sections of this catalog.

Students may obtain test information from <https://PearsonPTE.com>. (<https://PearsonPTE.com/>)

### IV. Attend and satisfactorily complete an Intensive English Program (IEP) within Missouri S&T's Applied Language Institute.

Students who enroll in an IEP must complete that program to the satisfaction of its director and academic coordinator (i.e. satisfy all graduation requirements) before they are allowed to enroll in full-time academic coursework. A student enrolled in an IEP may simultaneously enroll for a part-time academic course load with the approval of his or her academic department chair or designate, the director of the intensive English program, and the dean of graduate studies. Students may also submit proof of successful completion of a commission on English language program accreditation (CEA) recognized English as a second language (ESL) program.

### International Transfer Students

An international student enrolled in another American college or university is eligible to transfer to Missouri S&T if he or she meets the following criteria:

- has been enrolled full-time at the school he or she was last authorized to attend during the term immediately preceding the transfer or last preceding vacation period
- applies to and is accepted at Missouri S&T
- plans to be a full-time student at Missouri S&T
- is financially able to attend Missouri S&T

### International students must

- Pay all expenses while at Missouri S&T. In most departments, financial assistance, in the form of research and/or teaching assistantships, is available to some qualified applicants. International students are encouraged to contact the academic department to apply for these competitive assistantships.

- Submit a health history and immunization record to the Missouri S&T Health Services office.

Contact the Missouri S&T international and cultural affairs office (ia@mst.edu) regarding required immigration documents for SEVIS transfer within the United States.

### Application Deadlines for International Students

Application materials for overseas students and international students who are already in the U.S. but who want to transfer to Missouri S&T into a different degree level or into a different degree program must be received in the Missouri S&T office of admissions by the following dates:

- Fall semester – June 15
- Spring semester – November 15
- Summer session – April 1

Application materials for stateside applicants transferring to Missouri S&T at the same degree level and the same degree program (straight transfer) must be received in the Missouri S&T office of admissions by the following dates:

- Fall semester – July 15
- Spring semester – December 15
- Summer session – May 1

Applications, transcripts, English proficiency test scores (if applicable), required immigration documents, and any other materials required by an individual degree program must be received by the above dates in order to facilitate the student's admittance to Missouri S&T. Students whose credentials are not complete or are still being processed by the above dates may have their admission delayed. Students are strongly encouraged to submit their complete application package as early as possible, to ensure that all documents can be processed in a timely manner.

### Readmission After a Lapse in Enrollment

Main campus students who do not register for one semester must complete and submit a Former Graduate Student Refresh Registration (SRR) Eligibility Form (available at <http://registrar.mst.edu>) in order to reinstate their registration. Distance education students who do not register for three consecutive semesters must complete and submit the SRR form to reinstate their registration. A returning student can use this form to reestablish his or her admission status, provided that the student:

- has a graduate GPA greater than 3.0
- has received fewer than nine credit hours of F and/or C grades
- has taken his or her first graduate course within the past six years
- has taken fewer than twelve credit hours under probational master's status

All these criteria must be met in order for the student to reestablish active status as a regular graduate student. If any of these criteria are not met, the student must reapply for graduate admission to his or her former department. A student who wishes to change departments or change from non-degree status to regular or probational graduate status must submit a complete graduate admissions application package to his or her prospective department.

## Admission Categories and Graduate Student Classifications

Graduate students at Missouri S&T are admitted or classified in one of the following categories:

### Regular Status

Admission as a regular graduate student is normally limited to those who ranked in the upper third of their baccalaureate graduating class or who have done quality work at the graduate level. For this requirement, a cumulative B average (3.0 GPA on a 4.0 scale), or a B average (3.0 GPA on a 4.0 scale) for the student's last sixty credit hours of undergraduate coursework is considered equivalent to an upper one-third standing. If the student's undergraduate coursework does not meet the standards of the graduate degree granting department, the student may be required to take additional courses, for non-graduate credit, as determined by the chair or designate of the academic department. For more specific information about minimum GPA requirements, please consult your prospective department's website or entry in the areas of study section of this catalog.

### Probational Status

Any person not eligible for admission as a regular graduate student may be considered for admission as a probational graduate student. Probational graduate admission is normally limited to those students who ranked in the upper one-half of their baccalaureate graduating class, or who have achieved at least a cumulative 2.75 GPA (on a 4.0 scale) for their entire undergraduate career, or a 2.75 GPA (on a 4.0 scale) for their last sixty credit hours of undergraduate coursework. Minimum GPA requirements for particular departments may be set higher, so please consult your prospective department's website or entry in the areas of study sections of this catalog for more specific information.

Any probational graduate student who subsequently desires to pursue a degree as a regular graduate student may apply to change his or her status from "probational" to "regular." However, such consideration is not permitted until the probational graduate student has completed a minimum of twelve credit hours of graduate coursework with a cumulative grade point average of 3.0 or higher. After these initial twelve hours are completed satisfactorily, the probational student may, with the concurrence of his or her advisor, apply for regular student status by submitting Form 1. The approval of Form 1 by the department chair and the dean of graduate studies confers "regular" status to a formerly "probational" graduate student.

Only those credits completed as a probational graduate student that are subsequently approved by the student's advisor, department chair, and dean of graduate studies may be applied toward a graduate degree. However, all coursework completed as a probational graduate student, as well as the student's GRE scores, will be considered relevant to this change-of-status decision. Probational graduate students may retain their probational status for no more than one additional semester after completing their first twelve hours of graduate coursework. Regardless of the student's admission status, all completed graduate coursework (excluding 5000, 6000, and graduate research) will apply toward the student's cumulative GPA. Students with probational status are not allowed to register for graduate research credit until the semester in which the minimum of twelve credit hours of graduate coursework that form the proposed schedule on Form 1 will be completed.

## Non-degree Status

Any prospective student who wishes to study at the graduate level but who does not intend to pursue a graduate degree or graduate certificate may be considered for admission as a non-degree graduate student. Typically, this category of admission applies to, but is not restricted to, individuals who have a job-related need for a particular graduate-level course. Admission to non-degree graduate student status requires an application form, official transcripts, and an application fee, but neither GRE nor GMAT scores are required. Prospective students seeking admission in this category are encouraged to refer to their prospective department's website or entry in the areas of study section of this catalog for further department-specific information regarding non-degree status admission requirements.

Non-degree students may enroll in any graduate course as long as they meet the course prerequisite(s). Up to nine hours of graduate coursework taken as a non-degree student may be counted toward a Missouri S&T graduate degree or graduate certificate program, if applicable. Furthermore, if a student initially enrolls as a non-degree student and is subsequently accepted into a graduate degree or graduate certificate program before completing a particular course, that course may be accepted toward the graduate degree program subject to approval by the student's advisor, department chair, and the dean of graduate studies.

Students who must take particular undergraduate courses due to their different or deficient undergraduate degree, or for any other reason, but who otherwise meet graduate admission requirements are encouraged to apply for graduate admission by the first semester that they plan to take one or more graduate courses. These students must receive permission from their department in order to enroll in these graduate courses.

## Dual Enrollment Student Status

Undergraduate students may apply for dual enrollment as both an undergraduate and a graduate student. A student who seeks dual enrollment must submit an application to the office of admissions. Admission for dually enrolled students is granted by the department chair and the dean of graduate studies. Students are eligible to enroll when they have obtained senior status, with a minimum GPA of 3.5 if two semesters remain, 3.0 if in their final semester. Students must declare which courses are to be taken for graduate credit within the first two weeks of the semester. A dually enrolled student must take at least three hours of undergraduate credit from Missouri S&T each semester. Dually enrolled students are limited to sixteen total credit hours per semester, but petitions for additional credit hours will be considered by the dean of graduate studies. Dual enrollment forms are available at <http://registrar.mst.edu/media/administrative/registrar/documents/dualenrolled.pdf>. If a dually enrolled student fails to meet minimum undergraduate scholastic standards, his or her resulting academic probationary status will be that of an undergraduate and will be evaluated without reference to the student's grades in his or her graduate course(s).

## Grad Track Pathway

Some departments offer a Grad Track Pathway to exceptional undergraduate students for early provisional admission to the master's degree program. This accelerated program is designed for such students to earn coursework credits toward their master's degree while completing their bachelor's degree in a discipline as approved by the prospective graduate program. A Grad Track Pathway is defined by a set of graduate-level courses (no more than nine credit hours) that apply towards the bachelor's degree and then also towards their associated master's

degree. Please consult your (prospective) department for additional information.

## Graduate Student Forms

With the help of their advisors and department chairs, all graduate students must complete and submit a series of forms to the office of graduate studies throughout the course of their degree programs. These forms are used to indicate academic intentions, details of degree programs, membership of advisory committees, and performance on various examinations. All graduate student forms are available online at <http://grad.mst.edu/currentstudents/forms/>.

## Graduate Student Appeals

Graduate students at Missouri S&T have the right to appeal decisions made about their performance or their status. For details regarding the appeals procedure, please refer to the Student Academic Regulations Handbook, available online at <http://registrar.mst.edu/academicregs/>.

## Graduate Student Registration

The graduate student registration guidelines are outlined in Policy Memorandum No. II-20, which is available at <http://chancellor.mst.edu/policy/>. The policies below are taken directly from that document.

### A. Registration Guidelines for All Graduate Degree Candidates

1. Graduate students must remain continuously enrolled each fall and spring semester until the completion of their degree program. Graduate students not using campus resources\* during a summer session are not required to be enrolled in that session.
2. Full-time enrollment for graduate students is nine credit hours for each fall and spring semester and three credit hours for a summer session. Graduate students using campus resources will enroll for credits consistent with their usage, as determined by their department and their own needs for credit, but no less than three credit hours each fall and spring semester and summer session prior to meeting degree requirements.
3. Once all requirements have been met, with the exception of the master's comprehensive exam or final defense and acceptance of the final thesis/dissertation, and the student is using campus resources, one credit hour (charged as outlined on the current fee schedule based on individual residency/program status) of special problems (master's non-thesis students) or graduate research (master's thesis/doctoral students) will be considered as full-time enrollment each semester/session until the degree is completed. Students receiving funding may be subject to additional enrollment requirements.
4. When a graduate student takes the master's comprehensive exam, doctoral qualifying exam, doctoral comprehensive exam, or defends their thesis/dissertation, they must be enrolled on the date of the exam/defense. Failure to do so may invalidate the exam/defense. If the exam/defense occurs during the intercession, then an examination-only fee is appropriate by enrolling in one credit hour of Oral Examination 5040/6040. Intercession, for the purposes of this section, refers to the specific interval of time between the closing date of one academic semester/session and beginning of classes for the academic semester/session that immediately follows.
5. For students who have passed their final defense, the final copy of their thesis/dissertation must be accepted by the Office of Graduate Studies no later than the Friday before the next semester/session begins or they will be required to enroll in at least one credit hour of

graduate research (charged as outlined on the current fee schedule based on individual residency/program status) for the following semester/session. Only one semester/session of enrollment after passing the final defense will be allowed.

- All graduate teaching and research assistants (GTA/GRA), graduate assistants (GA), graduate instructors, and graduate fellows are required to be enrolled for at least nine credit hours each fall and spring semester and three credit hours each summer session. A one-time only exit semester exemption of full-time enrollment may be allowed, but must be no less than three credit hours.
- On-campus graduate students conducting off-campus research for credit must obtain advance approval from the department chair and the Office of Graduate Studies.

## B. Other Registration Guidelines for Candidates for a Doctoral Degree

- After passing the comprehensive examination and completing all coursework and residency requirements for the doctoral degree, the student must remain enrolled each fall and spring semester and summer session until completion of the degree. Failure to do so may invalidate the candidacy.
- Once all requirements have been met, with the exception of the final defense and acceptance of the final dissertation, and the candidate is not using campus resources\*, the student may enroll in one credit hour of Continuous Registration, 6050, each semester/session until the degree is completed. Failure to do so may invalidate the candidacy.
- Once the Continuous Registration Form is approved, registration and billing will be automatic for each semester/session until the degree is completed. Interruption of continuous registration due to failure to comply (e.g., non-payment) may result in the need for readmission under requirements then in effect.

The enrollment requirements do not supersede the minimum requirements of other offices or agencies.

\*University resources include but are not limited to: student health, library, recreation facilities, faculty/staff at Missouri S&T, etc.

## Graduate Assistantship Permissible Schedules

Graduate students enrolled in a full-time academic program may enroll in no more than sixteen credit hours of coursework during any regular semester and nine credit hours during the summer session, except for those students enrolled in the eighteen-credit-hour MBA core semester. Graduate students who are employed by the university as graduate instructors, teaching fellows, or graduate teaching and research assistants may not exceed a total of eighteen credit hours during a regular semester or nine credit hours for the summer session of combined coursework and employment assignment. The credit-hour equivalent for graduate teaching appointments varies according to how many hours the student teaches. The chart below outlines permissible schedules for graduate instructors, teaching fellows, and graduate teaching and research assistants. The "appointment" column indicates the level of employment assigned to a graduate student. A 0.25 FTE, full time equivalent, appointment requires approximately ten hours per week of effort; a 0.375 FTE appointment requires approximately fifteen hours per week of effort; a 0.50 FTE appointment requires approximately twenty hours per week of effort; and a 0.75 FTE appointment requires approximately thirty hours per week of effort. Graduate instructors accept

the responsibilities of a full-time position that requires forty hours per week of effort. The time commitment of each teaching fellow varies. The "credit hours of coursework" columns indicate the maximum number of academic credit hours in which a student with a particular appointment may enroll during a semester or summer session.

### Credit Hours of Coursework

Appointment	Regular Semester	Summer Session
0.250 FTE Grad. Asst.	14	7
0.375 FTE Grad. Asst.	13	6
0.500 FTE Grad. Asst.	12	6
0.625 FTE Grad. Asst.	11	5
0.750 FTE Grad. Asst.	10	5
Graduate Instructor	8	4
Teaching Fellow	9	0

In addition to the above schedule, any graduate student may enroll for no more than one credit hour in graduate seminar courses in a given semester.

## Enrollment Requirements and Funding Structure for Students on GTA/GRA/GA of 0.25 FTE or More

Graduate assistants employed by Missouri S&T as graduate assistants (GA), graduate teaching assistants (GTA), graduate research assistants (GRA), or who receive university or departmental fellowships at the 0.25 FTE or higher level, are expected to enroll in at least nine credit hours per academic semester. Students hired in these positions will pay regular educational fees for the first six hours; the educational fees for up to a total of three hours beyond the first six hours will be covered. This policy is known as the 6/9 rule. All other charges and fees, including the engineering course supplementary fee, are not covered. Furthermore, only courses for the graduate degree that are approved on Forms 1,1-A, or 5,5-A, or prerequisites for these courses, shall be covered by the 6/9 rule.

All graduate funding is subject to change.

## Enrollment Requirements and Funding Structure for Doctoral Students on GTA/GRA/GA of 0.375 FTE or More

Doctoral graduate assistants employed by Missouri S&T as graduate assistants (GA), graduate teaching assistants (GTA), graduate research assistants (GRA), or who received university or departmental fellowships at the 0.375 FTE or higher level are expected to enroll in at least nine credit hours per academic semester. Doctoral students hired in these positions will have educational fees and supplemental fees covered for those courses in their primary program of study. All other charges and fees are not covered. Furthermore, only on-campus courses for the graduate degree that are approved on Forms 5 and/or 5-A shall be covered.

Students pursuing a doctoral degree program after a master's degree program may receive four years of tuition and supplemental fee coverage. Students pursuing a doctoral degree program directly after a bachelor's degree program may receive five years of tuition and supplemental fee coverage.

Funding is only available for a student's primary program of study. Additional programs are ineligible. If a student changes their primary program, funding will only be available for the total years of coverage listed above and no longer, even if the change results in a longer degree completion time frame.

All graduate funding is subject to change.

## Enrollment Requirements and Funding Structure for Master's Students in Non-Doctoral Granting Departments on GTA/ GRA/GA of 0.375 FTE or More

Master's students in non-doctoral granting departments employed by Missouri S&T as graduate assistants (GA), graduate teaching assistants (GTA), graduate research assistants (GRA), or who received university or departmental fellowships at the 0.375 FTE or higher level are expected to enroll in at least nine credit hours per academic semester. Master's students in non-doctoral granting departments hired in these positions will have educational fees and supplemental fees covered for those courses in their primary program of study. All other charges and fees are not covered. Furthermore, only on-campus courses for the graduate degree that are approved on Forms 1 and/or 1-A shall be covered. Master's students eligible for the funding can receive two years of tuition and supplemental fee coverage.

Funding is only available for a student's primary program of study. Additional programs are ineligible. If a student changes their primary program, funding will only be available for the total years of coverage listed above and no longer, even if the change results in a longer degree completion time frame.

All graduate funding is subject to change.

## Grading System for Graduate Students

Grades in graduate courses, with the exception of the below listed pass/fail courses, are A, B, C, and F. "A" is an honor grade and indicates outstanding work. "B" means that the work is entirely satisfactory. "C" means that the work will be considered satisfactory, to a limited extent, in fulfilling the requirements for advanced degrees. "F" means that the student has not earned credit for the course. 6050, 5080/6080, 5085/6085, and graduate research grades are satisfactory (S) and unsatisfactory (U). Grades of "S" and "U" are also permitted for courses numbered 5000, 5010, 6000, and 6010. For ongoing graduate research, a delayed grade (DL) can be used. Delayed grades are sometimes assigned to students enrolled in graduate research until all of the research has been satisfactorily completed and the thesis or dissertation is successfully defended. Delayed grades may be changed to "S" upon satisfactory completion of the research or "U" if the research is not satisfactorily completed.

The grade of incomplete (I) is given only at the end of a semester or session in which the student is prevented from completing a course due to sickness or unavoidable absence within the last four weeks of a semester or session (three weeks of class plus finals week). Incomplete grades can be assigned only if the student had earned a passing grade in the course up to the time of such sickness or unavoidable absence. Effective Winter 2001, students must complete the work in which they are deficient within one year from the close of the semester in which the Incomplete (I) grade was recorded. Failure to do so will cause the incomplete grade to be changed automatically to an "F" or a "U." Effective

Fall 1992, a student may not withdraw from a course in which he or she receives a grade of incomplete.

## GPA Requirements for Graduate Students

In order to earn a graduate degree or graduate certificate, all students must achieve a cumulative GPA of 3.0 or higher in all graduate work taken at Missouri S&T. Master's and doctoral students must also achieve a GPA of 3.0 or higher for all graduate courses listed on the plan of study (Form 1 for master's students and Form 5 for doctoral students). No substitutions may be made on the plan of study for courses in which the student has earned less than a B grade. All graduate students are encouraged to maintain at least a 3.0 cumulative GPA at all times, and certain departments may even require this minimum GPA. In cases where a graduate student repeats a course, both the original and repeat grades will be used in calculating the student's GPA, and both will appear on the student's transcript.

If the semester graduate GPA falls below 3.0 the student will be placed on probation for the following semester. If the graduate GPA is not 3.0 or above in the following semester that coursework is taken, the student shall no longer be a candidate for a graduate degree or certificate from Missouri S&T.

## Course Time Limits

All graduate credit will only be valid if earned within the previous ten years, with no possible extension. This ten-year time limit does not apply to graduate credit that has been used toward a previously awarded degree or certificate.

## Graduate Learning Outcomes

The Graduate Learning Outcomes for Missouri University of Science and Technology as required by the Higher Learning Commission are listed below:

1. Knowledge: an ability to apply knowledge of subject matter within their field of study
2. Communication: an ability to communicate effectively within their field of study
3. Critical Thinking: an ability to engage in productive critical thinking within their field of study
4. Professional Development: an ability to develop professionally within their field of study.

## Master's Degrees

### Master's Degree Programs

Missouri S&T offers the master of science degree, the master of business administration degree (MBA), the master of engineering degree, the master of science for teachers degree, and the master of arts degree (offered in cooperation with the University of Missouri-St. Louis).

The information provided in this section outlines the minimum requirements established by the graduate faculty of the Missouri University of Science and Technology. Individual programs may have additional requirements set by the academic department. More information about each specific degree program is available on the departmental websites and in the areas of study sections of this catalog.

## Time Limits

Once admitted to a master's program, a student will be given six years to complete the program. A student may take a leave of absence, up to one year only, which will not count toward the six-year time limit. To apply for a leave of absence the student must consult with their academic advisor to complete the Leave of Absence Request form and submit for approval, first to the department chair and then to the dean of graduate studies.

## Plan of Study

During the semester a student will have completed nine hours of graduate credit, the student must formally plan the remainder of their graduate program in consultation with their academic advisor (and selected committee members, if applicable), and submit a Form 1 for approval, first to the department chair and then to the dean of graduate studies. Within that semester, the office of graduate studies will place a registration hold on the student's account for the following semester, which will be released upon acceptance of the Form 1. Courses applied toward one master's degree cannot also be applied toward another master's degree.

A student will be formally accepted as a candidate for a master's degree after their Form 1 has been approved by the academic advisor (and advisory committee, if applicable), the department chair, and the dean of graduate studies.

If changes to the approved Form 1 occur at any time, the candidate must submit a Form 1-A to revise their approved plan of study.

## Academic Advisor Requirements

All students pursuing a master's degree will have an academic advisor (and co-advisor, if applicable) who must be a member of the Missouri S&T graduate faculty. If the academic advisor does not hold an appointment in the student's academic department, a faculty member in that department must be designated as a co-advisor.

## Transferring Credits

A maximum of nine credit hours of coursework may be transferred from another university as long as these credits have not been used to meet the requirements of another degree and were registered as graduate credit when they were taken. Students must have earned at least a B grade or equivalent for all courses to be transferred to a Missouri S&T master's program, and must be entered as part of the student's plan of study on the Form 1/1-A. The Missouri S&T equivalent must be stated, and a transcript that includes the course(s) to be transferred should accompany the Form 1/1-A. Approval of the Form 1/1-A will allow the transferred course(s) to be entered on the student's Missouri S&T transcript, but only after the registrar's office has received the student's official transcript(s) from their previous school(s).

## Earning a Second/Subsequent Master's Degree

A student who has earned a master's degree at Missouri S&T or elsewhere in one major shall be eligible to earn a second/subsequent master's degree in another area upon satisfactory completion of a minimum of twenty-four additional hours of graduate credit (thesis or non-thesis). The plan of study (Form 1/1-A) must include a minimum of eighteen credit hours of 4000-, 5000-, and 6000 level lecture courses (1000/2000-level courses cannot be included). A minimum of six credit hours of the required coursework must come from the group of 6000-level lecture courses. Additionally, for a second/subsequent master's degree with a thesis, a minimum of six credit hours of graduate research is required.

## Master of Science Degree with Thesis

The master of science degree with thesis is designed for students who wish to earn an advanced degree while conducting original research under their academic advisor. The research during this program will culminate into a thesis that is likely to be published, and students will be required to present their thesis in an oral defense. This program gives students the opportunity to sharpen their research, writing, and presentation skills, and is a great option for those going into research-intensive fields or planning to pursue a doctoral degree.

### General Requirements for the Master of Science Degree with Thesis

The master of science degree with thesis requires a minimum of thirty hours of graduate credit. The plan of study (Form 1/1-A) must include a minimum of eighteen credit hours of 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). A minimum of six credit hours of the required coursework must come from the group of 6000-level lecture courses. Additionally, a minimum of six credit hours of graduate research is required. If a student has co-advisors in different departments, the student's graduate research credit may be shared by all departments involved.

Research will normally be conducted on the Missouri S&T campus, but in special cases, all or part of the research may be conducted elsewhere. Off-campus research must have the prior written approval of the student's academic advisor, department chair, and the dean of graduate studies (the application to do non-resident research is available at <http://grad.mst.edu/currentstudents/forms/>). Care must be taken to ensure that an off-campus research endeavor will result in educational experiences equivalent or superior to those that a student might expect to have at Missouri S&T.

### Committee Requirements for the Master of Science Degree with Thesis

For students pursuing the master of science degree with thesis, the committee will be designated on the plan of study (Form 1/1-A). The committee must consist of a minimum of three members. The academic advisor will serve as the chairperson of the thesis advisory committee. The advisor and at least half of the other committee members must be members of Missouri S&T graduate faculty. If a committee member is not a member of the Missouri S&T graduate faculty, a vita verifying equivalent level (or higher) of education must be provided with the Form 1/1-A.

Students are encouraged to make effective use of their advisory committee members by:

- Submitting a written description of the proposed research to the members of the committee as soon as the topic is decided.
- Obtaining written approval of the committee indicating that the proposed research is of the appropriate level of caliber.
- Submitting periodic progress reports to the committee and discussing these reports with individual committee members or with the committee as a group. The frequency of reports and the method of discussion should be determined by the committee.

## Thesis

The findings and results of research undertaken by the candidate must be presented in a written thesis. The thesis should embody the results of an original investigation and must represent significant, creative, and independent work. A manual entitled "Thesis & Dissertation



Specifications" is available at <http://grad.mst.edu/currentstudents/thesisdissertationinformation/formatting/>. This manual outlines the specific requirements for the thesis.

### **Final Examination (Defense)**

When the thesis is completed the candidate arranges a date, time, and location for the final examination (defense) of the thesis and distributes a copy to each member of their advisory committee at least seven days prior. The defense should be scheduled only during days the university is conducting normal business operations, and the candidate must be enrolled at the time of the defense.

The defense may be comprehensive in character, and the candidate should be able to demonstrate an acceptable level of knowledge of a professional area, as defined by their degree program. The defense must be presented as an oral examination and attendees may question the candidate with the permission of the chair of the advisory committee.

A candidate will be considered to have passed the defense if all, or all but one, of the advisory committee members vote that the candidate pass. If the candidate fails the defense, the committee will recommend additional work or other remedial measures to be taken before another defense is scheduled. A student who fails a second time will no longer be eligible to receive a graduate degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept them.

### **Approval of Defense and Thesis**

At the close of a successful defense, the members of the advisory committee will sign the Form 2 to signify that they have examined the thesis closely for both scientific content and format, and determined that it meets the requirements for a master's degree and is worthy of acceptance by the Missouri S&T graduate faculty. If the committee indicates that corrections must be made to the thesis, the candidate must make such corrections and then seek approval of the revised thesis from the committee members and obtain the necessary signatures. The chair of the advisory committee will report the results by submitting the Form 2, first to the department chair and then to the dean of graduate studies. After the Form 2 has been submitted and the office of graduate studies approves the format of the document, the candidate will be given instructions for final submission based on the release information provided on the Form 2.

### **Final Thesis Release Information**

The academic advisor will indicate how the final thesis will be released on the Form 2. There are three options available; immediate release, one-year hold, or indefinite hold. If immediate release or one-year hold is selected, the final thesis must be submitted electronically to the electronic thesis/dissertation (ETD) website. If indefinite hold is selected the final thesis must be printed and submitted to the office of graduate studies. The final thesis must not be submitted until instructions are provided from the office of graduate studies.

### **Procedures for Earning the Master of Science Degree with Thesis**

All master's degree students must have fulfilled all admissions requirements, including English proficiency test scores, if necessary. Students admitted to a master of science degree program and who are writing a thesis must adhere to the following procedures.

1. The student will consult with their academic advisor about course scheduling and registering for classes.

2. During the semester a student will have completed nine hours of graduate credit, the student must formally plan the remainder of their graduate program in consultation with their academic advisor and selected committee members, and submit the Form 1 for approval, first to the department chair and then to the dean of graduate studies. Students who fail to comply with the deadline to submit the Form 1 will have a registration hold placed on their account by the office of graduate studies.
3. The candidate will complete academic requirements included on their plan of study.
4. The candidate will apply for graduation through their Joe'SS account by the deadline posted by the registrar's office.
5. The candidate will arrange a date, time, and location for the defense. The candidate must be enrolled at the time of defense.
6. The candidate will distribute copies of the thesis to all members of the advisory committee at least seven working days before the defense.
7. The candidate must submit a complete copy of the thesis to the office of graduate studies to begin the format checking process.
8. The candidate holds the defense.
9. The chair of the advisory committee will report the results by submitting the Form 2, first to the department chair and then to the dean of graduate studies. Once the format check is complete and the Form 2 has been received, the office of graduate studies will direct the candidate to submit the final copy of the thesis.
10. Upon departmental request, the candidate may present one or more copies of the final thesis to the department.
11. The Board of Curators will, upon the recommendation of the graduate faculty, grant the candidate the master of science degree when all degree requirements are met and all enrollment or examination fees have been paid.

## **Master of Science Degree without Thesis**

The master of science degree without thesis is primarily designed for students who wish to earn an advanced degree without focusing on research. Students who choose this option will have a more classwork-focused plan of study and will usually earn their degree more quickly than the thesis option. This program provides a more flexible option for students who wish to specialize their knowledge by taking more classes rather than participating in a large-scale research project.

### **General Requirements for the Master of Science Degree without Thesis**

The master of science degree without thesis requires a minimum of thirty hours of graduate credit. The plan of study (Form 1/1-A) must include a minimum of twenty-four credit hours of 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). A minimum of nine credit hours of the required coursework must come from the group of 6000-level lecture courses. Additionally, no credit hours of graduate research may be applied toward the plan of study.

### **Comprehensive Examination for the Master of Science Degree without Thesis**

Some departments require candidates to take a comprehensive examination (biological sciences, chemistry, english and technical communication). If required, the candidate must successfully complete a final written comprehensive examination that is administered by an examining committee.

For candidates whose department requires a comprehensive examination, a committee will be designated by submitting the Form 1-B, first to the department chair and then to the dean of graduate studies. The committee must consist of at least five members, one of which must be from outside the candidate's major department. The chair and at least half of the committee members must be members of the Missouri S&T graduate faculty. If a committee member is not a member of graduate faculty, a vita verifying equivalent level (or higher) of education must be provided with the Form 1-B.

The comprehensive examination will be given in the candidate's final semester. The candidate must be enrolled at the time of the examination. The candidate will receive a passing grade if all, or all but one, of the members vote to pass. Results of the comprehensive examination must be submitted on the Form 3, first to the department chair and then to the dean of graduate studies. A student who fails the examination twice will no longer be eligible to receive a graduate degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept them.

## Master of Engineering Degree (M.E.)

The master of engineering degree is designed for full-time students who are able to complete the degree requirements on campus within a single year, as well as for students who have jobs in industry and who thus choose to access this program through distance education. The M.E. degree is practice-oriented, and students are expected to complete a significant project in the course of their studies.

### General Requirements for the Master of Engineering Degree (M.E.)

The master of engineering degree requires a minimum of thirty hours of graduate credit. The plan of study (Form 1/1-A) must include a minimum of twenty-four credit hours of 4000-, 5000-, 6000- level lecture courses (1000/2000-level courses cannot be included). A minimum of six credit hours of the required coursework must come from the group of 6000-level lecture courses. A minimum of three credit hours of practice-oriented project is required for all M.E. candidates. Additionally, no credit hours of graduate research may be applied toward the plan of study.

## Master of Business Administration Degree (MBA)

The business and information technology department offers a unique master of business administration degree. The MBA degree integrates core business knowledge and the latest information technology, management, leadership, and entrepreneurship knowledge. In addition to developing influential presentation skills and advanced problem-solving competencies, the MBA education develops advanced strategic thinking skills that are required of the leaders of today and tomorrow.

### General Requirements for the Master of Business Administration Degree (MBA)

The master of business administration degree requires thirty-six hours of graduate credit (1000/2000-level courses cannot be included). The plan of study (Form 1/1-A) must include a minimum of twenty-one credit hours of core coursework as required by the department. Additionally, no credit hours of graduate research may be applied toward the plan of study.

## Master of Science for Teachers Degree

The master of science for teachers degree is primarily designed for high school teachers in the sciences and mathematics who want to further their education and earn an advanced degree. The master of science for teachers degree is offered through the departments of chemistry, mathematics and statistics, and physics.

### General Requirements for the Master of Science for Teachers Degree

The master of science for teachers degree requires a minimum of thirty hours of graduate credit in science and mathematics as required by the department. The plan of study (Form 1/1-A) must include a minimum of twenty-four credit hours of 4000- 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). A minimum of three credit hours of the required coursework must come from the group of 6000-level lecture courses. Additionally, no credit hours of graduate research may be applied toward the plan of study.

## Master of Arts Degree

The departments of economics and English and technical communication at Missouri S&T have entered into a cooperative agreement with the corresponding departments at the University of Missouri-St. Louis to offer the master of arts degree in economics and English. This agreement permits students to take up to twelve hours of graduate credit on the Missouri S&T campus. However, students may take only nine credit hours at the 5000-level. Students interested in enrolling in this program are required to fulfill all admissions requirements, including English proficiency test scores, if necessary.

### Procedures for Earning a Master's Degree without Thesis

All master's degree students must have fulfilled all admissions requirements, including English proficiency test scores, if necessary. Students admitted to a master's degree program who are not writing a thesis must adhere to the following procedures.

1. The student will consult with their academic advisor about course scheduling and registering for classes.
2. During the semester a student will have completed nine hours of graduate credit, the student must formally plan the remainder of their graduate program in consultation with their academic advisor and submit the Form 1 for approval, first to the department chair and then to the dean of graduate studies. Students who fail to comply with the deadline to submit the Form 1 will have a registration hold placed on their account by the office of graduate studies.
3. The candidate will complete academic requirements included on their plan of study.
4. The candidate will apply for graduation through their Joe'SS account by the deadline posted by the registrar's office.
5. If the candidate is required to take the comprehensive examination (biological sciences, chemistry, English and technical communication):
  - A. The candidate will work with the academic advisor and the department chair to identify potential members of the students examining committee and then submit the Form 1-B to the dean of graduate studies for approval.
  - B. The candidate will take the written comprehensive examination.

- C. The chair of the examining committee will report the results by submitting the Form 3, first to the department chair and then to the dean of graduate studies.
6. The Board of Curators will, upon the recommendation of the graduate faculty, grant the candidate the master's degree when all degree requirements are met and all enrollment or examination fees have been paid.

## Doctoral Degree Programs

Missouri S&T offers the doctor of philosophy degree and the doctor of engineering degree.

The information provided in this section outlines the minimum requirements established by the graduate faculty of Missouri University of Science and Technology. Individual programs may have additional requirements set by the academic department. More information about each specific degree program is available on the departmental websites and in the areas of study sections of this catalog.

A person who has held the rank of assistant professor or higher at Missouri S&T is not eligible to become a candidate for the doctoral degree at this institution.

## Time Limit

Once admitted to a doctoral program, a student will be given eight years to complete the program. A student may take a leave of absence, up to one year only, which will not count toward the eight-year time limit.

To apply for a leave of absence the student must consult with their academic advisor to complete the Leave of Absence Request form and submit for approval, first to the department chair and then to the dean of graduate studies.

## Academic Advisor Requirements

All students pursuing a doctoral degree will have an academic advisor (and co-advisor, if applicable) who must be a member of the Missouri S&T graduate faculty. If the academic advisor does not hold an appointment in the student's academic department, a faculty member in that department must be designated as a co-advisor. If a student has co-advisors in different departments, the student's graduate research credit may be shared by all departments involved.

## Transferring Credits

Coursework may be transferred from another university as long as these credits have not been used to meet the requirements of another degree and were registered as graduate credit when they were taken. Students that do not hold a master's degree may transfer a maximum of eighteen credit hours and students that hold a master's degree may transfer a maximum of nine credit hours. Students must have earned at least a B grade or equivalent for all courses to be transferred to a Missouri S&T doctoral program, and must be entered as part of the student's plan of study on the Form 5/5-A. The Missouri S&T equivalent must be stated, and a transcript that includes the course(s) to be transferred should accompany the Form 5/5-A. Approval of the Form 5/5-A will allow the transferred course(s) to be entered on the student's Missouri S&T transcript, but only after the registrar's office has received the student's official transcript(s) from their previous school(s).

## Qualifying Examination

A qualifying examination will be administered by the student's academic department and the results must be reported on the Form 4 by the department chair to the dean of graduate studies. The results of this examination will allow the student's advisory committee to assess the student's level of preparation for the doctoral degree and will assist the committee in helping to plan the student's plan of study (Form 5). The qualifying examination must be passed no later than the end of the fifth semester of enrollment in a doctoral program. Students who fail to comply with the deadline to submit the Form 4 will have a registration hold placed on their account by the office of graduate studies. A student who fails the examination twice will no longer be eligible to receive a graduate degree from that program. However, the student is eligible to pursue a graduate degree from any other graduate degree program willing to accept them.

## Plan of Study

The beginning doctoral student should consult with their academic advisor to determine an appropriate degree plan. After the student has passed the qualifying exam, the student must formally plan the remainder of their graduate program in consultation with their academic advisor and selected committee members, and submit a plan of study (Form 5) for approval, first to the department chair and then to the dean of graduate studies. The Form 5 must be submitted by the end of the semester in which the student passes the qualifying examination. Students who fail to comply with the deadline to submit the Form 5 will have a registration hold placed on their account by the office of graduate studies.

A student will be formally accepted as a candidate for a doctoral degree after they pass the qualifying exam and their Form 5 has been approved by the advisory committee, the department chair, and the dean of graduate studies.

If changes to the approved Form 5 occur at any time, the candidate must submit a Form 5-A to revise their approved plan of study.

## Residency and Research Requirement

Residency at Missouri S&T is defined as sustained intellectual interactions among the student and the academic community. The candidate for a doctoral degree must complete a minimum of three years of residency, which is equivalent to at least six academic semesters while enrolled as an on-campus student at Missouri S&T. Students holding a master's degree are automatically credited with two semesters of residency. Residency must be documented on the student's plan of study (Form 5/5-A).

Students unable to meet the residency requirement given above, such as distance students, can meet this requirement through an alternative route. In consultation with their academic advisor, the student can utilize other experiences toward meeting the residency requirements. Such experiences include regular contact with the student's academic advisor, committee members, and other graduate students, participation in a seminar series, etc. Other experiences that would count toward earning residency are listed in a supplemental document available from the office of graduate studies. It is the responsibility of the student's academic advisor to document suitable residency experiences. This documentation must be included with the Form 5/5-A.

Research will normally be conducted on the Missouri S&T campus, but in special cases, all or part of the research may be conducted elsewhere. Off-campus research must have the prior written approval

of the student's academic advisor, department chair, and the dean of graduate studies (the application to do non-resident research is available at <http://grad.mst.edu/currentstudents/forms/>). (<http://grad.mst.edu/currentstudents/forms/>.)%20/) Care must be taken to ensure that an off-campus research endeavor will result in educational experiences equivalent or superior to those that a student might expect to have at Missouri S&T.

## Comprehensive Examination

After the candidate has completed at least 50% of the coursework required for the doctoral degree, as listed on their approved plan of study (Form 5/5-A), the advisory committee must request authorization to administer the comprehensive examination by submitting the Form 6A, first to the department chair and then to the dean of graduate studies. The candidate and department must receive written notification of authorization from the office of graduate studies prior to administering the examination.

The results of the comprehensive examination will be reported by submitting the Form 6B, first to the department chair and then to the dean of graduate studies. A candidate will be considered to have passed the examination if all, or all but one, of the advisory committee members vote that the candidate pass. If the candidate fails the comprehensive examination, the advisory committee will recommend additional work or other remedial measures to the candidate. A second comprehensive examination may be scheduled no sooner than twelve weeks after the candidate's first attempt. A student who fails the examination a second time will no longer be eligible to receive a graduate degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept them.

## Dissertation

The findings and results of research undertaken by the candidate must be presented in a written dissertation. The dissertation should embody the results of an original investigation and must represent significant, creative, and independent work. A manual entitled "Thesis & Dissertation Specifications" is available at <http://grad.mst.edu/currentstudents/thesisdissertationinformation/formatting/>. This manual outlines the specific requirements for the dissertation.

## Final Examination (Defense)

When the dissertation is completed, the candidate arranges a date, time and location for the final examination (defense) of the dissertation and distributes a copy to each member of their advisory committee at least seven days prior. The defense should be scheduled only during days the university is conducting normal business operations, and the candidate must be enrolled at the time of the defense. Additionally, there must be at least twelve weeks between passing the comprehensive examination and holding the defense. Details of the defense, along with the dissertation title and abstract, must be publicized by the office of graduate studies at least one week prior to the defense.

The defense may be comprehensive in character and the candidate should be able to demonstrate an acceptable level of knowledge of a professional area, as defined by their degree program. The defense must be presented as an oral examination and attendees may question the candidate with the permission of the chair of the advisory committee.

## Approval of Defense and Dissertation

A candidate will be considered to have passed the defense if all, or all but one, of the advisory committee members vote that the candidate pass. If the candidate fails the defense, the committee will recommend additional work or other remedial measures to be taken before another defense is scheduled. A student who fails a second time will no longer be eligible to receive a doctoral degree from that program. However, the student is still eligible to pursue a graduate degree from any other graduate degree program willing to accept them.

At the close of a successful defense, the members of the advisory committee will sign the Form 7 to signify that they have examined the dissertation closely for both scientific content and format, and determined that it meets the requirements for a doctoral degree and is worthy of acceptance by the graduate faculty of Missouri S&T. If the committee indicates that corrections must be made to the dissertation, the candidate must make such corrections and then seek approval of the revised dissertation from the committee members and obtain the necessary signatures. The chair of the advisory committee will report the results by submitting the Form 7, first to the department chair and then to the dean of graduate studies. After the Form 7 has been submitted and the office of graduate studies approves the format of the document, the candidate will be given instructions for final submission based on the release information provided on the Form 7.

## Final Dissertation Release Information

The academic advisor will indicate how the final dissertation will be released on the Form 7. There are three options available; immediate release, one-year hold, or indefinite hold. If immediate release or one-year hold is selected, the final dissertation must be submitted electronically to the electronic thesis/dissertation (ETD) website. If indefinite hold is selected the final dissertation must be printed and submitted to the office of graduate studies. The final dissertation must not be submitted until instructions are provided from the office of graduate studies.

## Doctor of Philosophy Degree (Ph.D.)

The doctor of philosophy degree is the highest level of academic achievement awarded and is designed for students to produce original research and make significant, independent contributions to their chosen field of study that expands the boundaries of knowledge. The research during this program will culminate into a dissertation that is likely to be published, and students will be required to present their dissertation in an oral defense.

## General Requirements for the Doctor of Philosophy Degree (Ph.D.)

Students who hold a master's degree will be required to complete a minimum of forty-two hours of graduate credit. The plan of study (Form 5/5-A) must include a minimum of twelve credit hours of 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). It is recommended that nine credit hours of the required coursework come from the group of 6000-level lecture courses. Additionally, a minimum of twenty-four credit hours of graduate research is required. A Ph.D. student who holds a master's degree will receive a block of thirty credit hours that can be included on the Form 5/5-A, which will count toward the total seventy-two-hour program requirement.

Students who do not hold a master's degree will be required to complete a minimum of seventy-two hours of graduate credit. The plan of study (Form 5/5-A) must include a minimum of thirty credit hours of 4000-,

5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). It is recommended that fifteen credit hours of the required coursework come from the group of 6000-level lecture courses. Additionally, a minimum of thirty credit hours of graduate research is required.

Credit from only one master's degree may be included on the doctoral plan of study (Form 5/5-A).

## Committee Requirements for the Doctor of Philosophy Degree (Ph.D.)

For students pursuing the doctor of philosophy degree, the committee will be designated on the plan of study (Form 5/5-A). The academic advisor will also serve as the chairperson of the dissertation advisory committee. The committee must consist of a minimum of five members and the academic advisor and at least three others must be members of the Missouri S&T graduate faculty. The advisory committee must include at least one member from outside the student's major department. If a committee member is not a member of the Missouri S&T graduate faculty, a vita verifying equivalent level of education must be provided with the Form 5/5-A.

Students are encouraged to make effective use of their advisory committee members by:

- Submitting a written description of the proposed research to the members of the committee as soon as the topic is decided.
- Obtaining written approval of the committee indicating that the proposed research is of the appropriate level of caliber.
- Submitting periodic progress reports to the committee and discussing these reports with individual committee members or with the committee as a group. The frequency of reports and the method of discussion should be determined by the committee.

## Procedures for Earning the Doctor of Philosophy Degree (Ph.D.)

All doctoral students must have fulfilled all admissions requirements, including English proficiency test scores, if necessary. Students admitted to a Ph.D. program must adhere to the following procedures.

1. The student will consult with their academic advisor about course scheduling and registering for classes.
2. The student passes a qualifying examination administered by the department in which the student intends to become a doctoral degree candidate.
3. After the student has passed the qualifying examination, the student must formally plan the remainder of their graduate program in consultation with their academic advisor and selected committee members, and submit the Form 5 for approval, first to the department chair and then to the dean of graduate studies. Students who fail to comply with the deadlines to submit the Form 4 and Form 5 will have a registration hold placed on their account by the office of graduate studies.
4. The student will be formally accepted as a candidate for the Ph.D. degree after they pass the qualifying examination and their Form 5 has been approved by the advisory committee, the department chair, and the dean of graduate studies.
5. After the candidate has completed at least 50% of the coursework required for the Ph.D. degree, as listed on their approved plan of study (Form 5/5-A), the advisory committee must request authorization

to administer the comprehensive examination by submitting a Form 6A, first to the department chair and then to the dean of graduate studies. The candidate and department must receive written notification of authorization from the office of graduate studies prior to administering the examination.

6. The results of the comprehensive examination will be reported by submitting the Form 6B, first to the department chair and then to the dean of graduate studies.
7. The candidate will complete the academic requirements included on their plan of study.
8. The candidate will apply for graduation through their Joe'SS account by the deadline posted by the registrar's office.
9. The candidate will arrange a date, time, and location for the defense and must inform the office of graduate studies electronically, as the defense must be publicized at least one week in advance. The defense must not be scheduled earlier than twelve weeks after passing the comprehensive examination and the candidate must be enrolled at the time of defense.
10. The candidate will distribute copies of the dissertation to all members of the advisory committee at least seven working days before the defense.
11. The candidate must submit a complete copy of the dissertation to the office of graduate studies to begin the format checking process.
12. The candidate holds the defense.
13. The chair of the advisory committee will report the results by submitting the Form 7, first to the department chair and then to the dean of graduate studies.
14. Once the format check is complete and the Form 7 has been received, the office of graduate studies will direct the candidate to submit the final copy of the dissertation.
15. Upon departmental request, the candidate may present one or more copies of the final dissertation to the department.
16. The Board of Curators will, upon the recommendation of the graduate faculty, grant the candidate the Ph.D. degree when all degree requirements are met and all enrollment or examination fees have been paid.

## Doctor of Engineering Degree (D.E.)

The doctor of engineering degree is the highest level of academic achievement awarded and is designed for students to develop the problem-solving and research skills to practice engineering in their field of study. The research and internship experience during this program prepares individuals for professional careers in business, industry and the public sector. This program will culminate into a dissertation that is likely to be published, and students will be required to present their dissertation in an oral defense.

## General Requirements for the Doctor of Engineering Degree (D.E.)

Students who hold a master's degree will be required to complete a minimum of sixty hours of graduate credit. The plan of study (Form 5/5-A) must include a minimum of twelve credit hours of 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included).

It is recommended that nine credit hours of the required coursework come from the group of 6000-level lecture courses. Additionally, a minimum of twenty-four credit hours of graduate research and twenty-four credit hours of graduate internship is required. A D.E. student who holds a master's degree will receive a block of thirty credit hours that can

be included on the Form 5/5-A, which will count toward the total ninety-hour program requirement.

Students who do not hold a master's degree will be required to complete a minimum of ninety hours of graduate credit. The plan of study (Form 5/5-A) must include a minimum of thirty credit hours of 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included).

It is recommended that fifteen credit hours of the required coursework come from the group of 6000-level lecture courses. Additionally, a minimum of thirty credit hours of graduate research and twenty-four credit hours of graduate internship is required.

Credit from only one master's degree may be included on the doctoral plan of study (Form 5/5-A).

## Internship for the Doctor of Engineering Degree (D.E.)

The internship for the doctor of engineering degree involves a minimum of one year of planned and approved high-level engineering experience. The candidate and the academic advisor will plan the internship in cooperation with the interning organization. The candidate then prepares a detailed proposal that describes the goals of the internship, the tasks to be accomplished, and the facilities at the intended site. This proposal must be approved by the candidate's advisory committee and the department chair prior to the start of the internship. At the time of approval, and prior to enrolling in graduate internship, the candidate's internship supervisor from the interning organization must be added to the advisory committee by submitting the Form 5-A, first to the department chair and then to the dean of graduate studies. The internship supervisor is to be selected on the basis of their qualifications of education and experience that suggest doctoral equivalency credentials. The interning organization must allow visits to the internship site by the candidate's academic advisor and/or advisory committee members. The interning organization must also agree that any results of the internship may be published by the candidate, although reasonable proprietary rights of the interning organization will be protected. Responsibility for arranging the internship, including site selection and financial compensation during the period of the internship, lies with the candidate.

## Committee Requirements for the Doctor of Engineering Degree (D.E.)

For students pursuing the D.E. degree, the committee will be designated on the plan of study (Form 5/5-A). The academic advisor will also serve as the chairperson of the dissertation advisory committee. The committee must consist of a minimum of five members and the academic advisor and at least three others must be members of the Missouri S&T graduate faculty. The advisory committee must include at least one member from outside the candidate's major department. If a committee member is not a member of the Missouri S&T graduate faculty, a vita verifying equivalent level of education must be provided with the Form 5/5-A.

Students are encouraged to make effective use of their advisory committee members by:

- Submitting a written description of the proposed research to the members of the committee as soon as the topic is decided.
- Obtaining written approval of the committee indicating that the proposed research is of the appropriate level of caliber.

- Submitting periodic progress reports to the committee and discussing these reports with individual committee members or with the committee as a group. The frequency of reports and the method of discussion should be determined by the committee.

## Procedures for Earning the Doctor of Engineering Degree (D.E.)

All doctoral students must have fulfilled all admissions requirements, including English proficiency test scores, if necessary. Students admitted to a D.E. program must adhere to the following procedures.

1. The student will consult with their academic advisor about course scheduling and registering for classes.
2. The student passes a qualifying examination administered by the department in which the student intends to become a doctoral degree candidate.
3. After the student has passed the qualifying examination, the student must formally plan the remainder of their graduate program in consultation with their academic advisor and selected committee members, and submit the Form 5 for approval, first to the department chair and then to the dean of graduate studies. Students who fail to comply with the deadlines to submit the Form 4 and Form 5 will have a registration hold placed on their account by the office of graduate studies.
4. The student will be formally accepted as a candidate for the D.E. degree after they pass the qualifying examination and their Form 5 has been approved by the advisory committee, the department chair, and the dean of graduate studies.
5. After the candidate has completed at least 50% of the coursework required for the D.E. degree, as listed on their approved plan of study (Form 5/5-A), the advisory committee must request authorization to administer the comprehensive examination by submitting a Form 6A, first to the department chair and then to the dean of graduate studies. The candidate and department must receive written notification of authorization from the office of graduate studies prior to administering the examination.
6. The results of the comprehensive examination will be reported by submitting the Form 6B, first to the department chair and then to the dean of graduate studies.
7. Prior to enrolling in graduate internship, the candidate's internship supervisor must be added to the advisory committee by submitting the Form 5-A, first to the department chair and then to the dean of graduate studies.
8. The candidate will complete the academic requirements included on their plan of study.
9. The candidate will apply for graduation through their Joe'SS account by the deadline posted by the registrar's office.
10. The candidate will arrange a date, time, and location for the defense and must inform the office of graduate studies electronically, as the defense must be publicized at least one week in advance. The defense must not be scheduled earlier than twelve weeks after passing the comprehensive examination and the candidate must be enrolled at the time of defense.
11. The candidate will distribute copies of the dissertation to all members of the advisory committee at least seven working days before the defense.
12. The candidate must submit a complete copy of the dissertation to the office of graduate studies to begin the format checking process.
13. The candidate holds the defense.

14. The chair of the advisory committee will report the results by submitting the Form 7, first to the department chair and then to the dean of graduate studies.
15. Once the format check is complete and the Form 7 has been received, the office of graduate studies will direct the candidate to submit the final copy of the dissertation.
16. Upon departmental request, the candidate may present one or more copies of the final dissertation to the department.
17. The Board of Curators will, upon the recommendation of the graduate faculty, grant the candidate the D.E. degree when all degree requirements are met and all enrollment or examination fees have been paid.

## Graduate Certificate and Minor Programs

### Graduate Certificate Programs

Missouri S&T offers a number of graduate certificates that are designed to appeal to those working professionals who are interested in furthering their education and who seek the knowledge to understand and contribute to an emerging area of their professional lives.

The information provided in this section outlines the minimum requirements established by the graduate faculty of Missouri University of Science and Technology. Individual programs may have additional requirements set by the academic department. More information about each specific graduate certificate program is available on the departmental websites and in the areas of study sections of this catalog.

### Time Limit

Once admitted to a certificate program, a student will be given three years to complete the program. A student may take a leave of absence, up to one year only, which will not count toward the three-year time limit.

To apply for a leave of absence the student must consult with their academic advisor to complete the Leave of Absence Request form and submit for approval, first to the department chair and then to the dean of graduate studies.

### Academic Advisor Requirements

All students pursuing a certificate will have an academic advisor who must be a member of the Missouri S&T graduate faculty.

### Transferring Credits

A maximum of one course (equivalent to at least three credit hours) may be transferred from another university as long as these credits have not been used to meet the requirements of another degree and were registered as graduate credit when they were taken. Students must have earned at least a grade of B or equivalent for the course to be transferred to a Missouri S&T certificate. The transfer course, the Missouri S&T equivalent, and the certificate course that is being replaced must be indicated on a Substitution for Required Course – Certificate Program form. A transcript that includes the course to be transferred must be attached to the form and submitted for approval, first to the department chair and then to the dean of graduate studies. Approval of the form will allow the transferred course to be entered on the student's Missouri S&T transcript, but only after the registrar's office has received the student's official transcript from their previous school.

## General Requirements

Certificate programs require the completion of twelve credit hours (four designated courses) of 3000-, 4000-, 5000-, and 6000-level lecture courses (1000/2000-level courses cannot be included). Courses taken for a specific certificate cannot be counted toward an additional certificate.

A Certificate Program Courses form must be signed by the student and the academic advisor for each certificate program and then submitted to the dean of graduate studies before the second or subsequent certificate can be awarded.

Certificate programs may be offered by more than one program and/or department, which must be chosen by the student upon application.

## Acceptance into a Master's Degree Program

If the four-course sequence is completed with at least a grade of B in each of the courses taken, the GRE/GMAT will not be required upon application into a master's program. However, all other program prerequisites and admission requirements must be met. If the certificate requirements are not met, students may still apply to the master's program of their choice, but normal admission requirements (including minimum GRE or GMAT scores) must be met.

The certificate courses can be applied toward a master's program. However, once the master's degree has been awarded, any courses used on that plan of study cannot be used for additional certificates, unless the certificate program admit term is prior to the awarding of the master's degree.

## Procedures for Earning a Graduate Certificate

1. Students must apply and be admitted to each certificate program.
2. The student will consult with their academic advisor about course scheduling and registering for classes.
3. The student will complete the required certificate coursework.
4. For students enrolled in and/or completing more than one certificate, a Certificate Program Courses form must be submitted for approval, first to the academic advisor for each certificate program and then to the dean of graduate studies, before the second or subsequent certificate can be awarded.
5. The student must apply for completion through their Joe'SS account by the deadline posted by the registrar's office.
6. The Board of Curators, upon the recommendation of the graduate faculty, grants the student the certificate when all requirements are met and all enrollment or examination fees have been paid.

## Graduate Minors

Students enrolled in master's or doctoral degree programs at Missouri S&T may designate a graduate minor if they choose. Designated graduate minors are offered by individual degree-granting departments. Requirements for the graduate minor are determined by the department offering the minor. Graduate minors can only be awarded when the major degree is awarded, and all requirements for the graduate minor must be completed while the candidate is working toward their major degree.

Any graduate student interested in pursuing a graduate minor should consult with their academic advisor. Applications for a designated graduate minor must be completed and submitted for approval to

the minor-granting department and must be approved at least one full semester prior to the candidate's planned graduation date. The application form for designated graduate minors is available at <http://registrar.mst.edu/forms/>. (<http://registrar.mst.edu/forms/>)



# RESEARCH CENTERS AND INSTITUTES

This section contains information about some of the research centers and institutes which graduate students may choose to collaborate or coordinate with during their academic career. Please navigate this section by using the menu at the left and selecting the category that best represents the type of research you wish to view. For more comprehensive information please visit the individual department websites.

## Center for Biomedical Research (CBR)

### 110D Engineering Research Lab Richard K. Brow (Interim Director)

A list of **Research Investigators** and information about their research interests can be found at <https://cbr.mst.edu/people/>

### What we do

The center for biomedical research promotes interdisciplinary collaboration to expedite scientific discovery and technological advances. Our goal is to develop next-generation materials, devices, and therapeutics for biomedical applications.

Researchers in the center lead research and education programs to train the next generation of biomedical engineers and scientists, to provide a future workforce for Missouri and the U.S.

We also promote technology transfer and entrepreneurship to commercialize new knowledge, and we collaborate with colleagues in hospitals and clinics around the State, and at other universities, to make these technologies available to the patients who will benefit from them.

### Research highlights

The multidisciplinary research investigators with the center for biomedical research are involved in many different studies, including:

- Scaffolds for tissue engineering, bone regeneration, and vascularization
- Traumatic brain injury treatments and prevention
- Regenerative medicine and stem cell biology
- Bioactive glass for wound healing and nerve regeneration
- Nano biomaterials for drug delivery, cancer treatment and diagnosis
- Biomarkers for cancer detection
- Antibacterial coatings and implants for orthopedic surgery
- Biosensors and bio-imaging devices

To contact us, please visit our web page at <http://cbr.mst.edu/> or e-mail: [cbr@mst.edu](mailto:cbr@mst.edu).

## Center for Infrastructure Engineering Studies (CIES)

### 223 Engineering Research Lab Kamal H. Khayat (Director) The Vernon and Maralee Jones Endowed Professor of Civil Engineering Staff

Jason Cox (Senior Research Specialist); Gayle Spitzmiller (Administrative Assistant).

### Researchers

Magdy Abdelrahman (CArE); Kwame Awuah-Offei (MNE); Rui Bo (ECE); Casey Canfield (EMSE); K. Chandrashekhara (MAE); Genda Chen (CArE); Maggie Cheng (CS); Steven Corns (EMSE); Wen Deng (CArE); Kristen M. Donnell (ECE); Islam H. El-adaway (CArE); Mohamed A. Elgawady (CArE); Nima Farzadnia (CIES); Dimitri Feys (CArE); Mao Chen Ge (MNE); Abhijit Gosavi (EMSE); Xiaoming He (Math); Xianbiao Hu (CArE); Jie Huang (ECE); Abdulmohsin Imqam (GSE); Kamal Khayat (CArE); Aditya Kumar (MSE); Benjamin Kwasa (EMSE); Nicholas Libre (CArE); Jenny Liu (CArE); Suzanna Long (EMSE); Steven Lusher (CArE); Hongyan Ma (CArE); Sanjay Madria (CS); John J. Myers (CArE); Monday Okoronkwo (ChemBio Engr); Guney Olgun (CArE); Jonghyun Park (MAE); Joontaek Park (ChemE); Ruwen Qin (EMSE); Thomas Schuman (Chem); Sahra Sedigh (ECE); Taghi Sherizadeh (MNE); Honglan Shi (Chem); Lesley Sneed (CArE); Jianmin Wang (CArE); Chenglin Wu (CArE); Cheng Hsiao Wu (ECE); Donald C. Wunsch (ECE); Guirong Yan (CArE); Xiong Zhang (CArE); Y. Rosa Zheng (ECE).

The Center for Infrastructure Engineering Studies (CIES) was created through the University of Missouri's Mission Enhancement Program at the Rolla campus. The center provides research expertise in the area of buildings and civil infrastructure and infrastructure management. The mission of CIES is to provide leadership in research and education for solving the problems affecting the nation's infrastructure systems. CIES is the primary conduit for communication among those on the Missouri S&T campus interested in infrastructure studies. The center provides coordination for collaborative, interdisciplinary efforts with emphasis on: (1) the development of advanced sustainable materials for infrastructure construction and rehabilitation; (2) deployment of advanced design methods to resist extreme events, such as earthquakes; and (3) development and use of novel, non-destructive techniques to assess damage and structural health monitoring of infrastructure.

Interdisciplinary research and development with projects tailored to address needs of federal agencies, state agencies, and private industry; technology transfer and continuing distance education to the engineering community and industry.

E-mail [cies@mst.edu](mailto:cies@mst.edu), visit our website at: <http://cies.mst.edu/> or phone: 573-341-4497.

## Center for Research in Energy and Environment (CREE)

### 101 Engineering Research Laboratory Jonathan Kimball (Interim Director)

The mission of the Center for Research in Energy and the Environment (CREE) is to support research in the broad field of energy—including traditional and alternative energy sources, energy storage, and energy delivery and usage—as well as research in biological, chemical, and physical systems involving emerging contaminants in natural and engineered systems. CREE brings together researchers from across the campus—including faculty in both the College of Engineering and Computing and the College of Arts, Sciences, and Business—to address the multi-faceted challenges of maintaining energy security while mitigating human impact on the environment.

Recent projects include a study of nano-engineered catalysts for producing syngas; 3D printing of battery components; extreme fast charging of electric vehicles; phytoforensics for contaminant tracking; and innovative approaches to obtain critical minerals needed for alternative energy. CREE research is supported by a wide range of industry sources as well as federal agencies such as the National Science Foundation, Department of Education, Department of Transportation, Nuclear Regulatory Commission, and the Environmental Protection Agency.

CREE laboratories support advanced research with chemical analysis instruments including high performance liquid chromatography (HPLC), gas chromatography with mass spectrometry (GC-MS), inductively coupled plasma-optical emission spectrometer (ICP-OES) and inductively coupled plasma mass spectrometry (ICP-MS), plus a variety of instruments used for sample preparation. CREE also includes the Center of Excellence for Aerospace Particulate Emissions Research, funded by NASA, FAA, the Department of Defense, and the EPA, with novel instruments tailored specifically to measuring and analyzing airborne particulates. Finally, CREE supports the unique Solar Village and EcoVillage living laboratories, which comprise six small houses with extensive solar, energy storage, and energy efficiency features.

## Cloud and Aerosol Sciences Laboratory (CASL)

### Norwood Hall Donald E. Hagen (Director) Faculty

R. W. Alexander (Emeritus Prof. Phys.); D.J. Alofs (Emeritus Prof. M&AE and EM); J.C. Carstens (Emeritus Prof. Phys.); N. Ercal (Chem); B.N. Hale (Phys.); S. Kapila (Chem.); U.O. Koylu (M&AE); P. Nam (Chem); J.L. Schmitt (Assoc. Prof. Emeritus, Phys.); D.R. White, (Assoc. Prof. Emeritus, B.E.); P.D. Whitefield (Chem.); G. Wilemski (Phys.).

Global, regional, and local environmental concerns have propelled the atmospheric sciences to international prominence. Well known issues such as the local air quality, ozone, acid rain, photo-chemical smog, and global warming attest to the urgency of atmospherically related problems now facing society.

CASL is a multidisciplinary effort drawing on the solid base of engineering and sciences provided by Missouri S&T. Students from various academic departments perform their thesis research within the laboratory in partial fulfillment of the M.S. or Ph.D. degree requirements of their "home" department.

The program is directed toward a fundamental understanding of the role of aerosols, including clouds and fogs, in our atmospheric environment. Current studies focus on the generation and environmental impact of anthropogenic combustion aerosols, basic nucleation processes of water and ice, cluster structure both in the gaseous phase and on substrates, homogenous binary nucleation, neutron scattering measurements on nanodroplet aerosols, particle formation in supersonic expansions, the heterogeneous chemistry and chemical composition of air borne aerosols and their impact on the atmosphere, and the behavior of aerosol particles in the human respiratory system.

CASL provides leadership in international and national research programs. It is the home for the Missouri S&T lead federal Center of Excellence for Aerospace Particulate Emissions Reduction Research, is a member of the FAA-NASA-Transport Canada Center of Excellence for Aviation Noise and Aircraft Emissions Mitigation, and leads the air related mission for the Missouri S&T Center for Emerging Contaminants. Its brief extends to particulate mitigation strategies for new combustor development.

The Laboratory houses a variety of instrumentation, much of it unique. This includes a finely tuned expansion chamber used to study nucleation phenomena, instrumentation designed to directly determine the chemical composition of particles on which droplets form, and an extensive mobile facility for both the on-ground and in-flight collection and analysis of combustion (e.g. jet exhaust) aerosols.

In addition to acquiring knowledge of cloud, aerosol, and atmospheric science, the laboratory imparts to students a familiarity with a wide variety of data acquisition, signal conditioning, and system engineering problems. Visit our website at <http://coe.mst.edu>.

## Energetics Research Facility

### Catherine Johnson, Assistant Professor [johnsonce@mst.edu](mailto:johnsonce@mst.edu)

This facility is the only one of its kind in a university environment. The Center has two blast-containment chambers, one rated for 1kg of explosives and the other rated for 4kg. In addition to workstations running advanced simulation software, the Center has explosion imaging equipment that includes an ultra-high speed Cordin 10-A framing camera (capable of 1,250,000 frames/sec), high-speed video cameras (a Phantom V2012, capable of 22,500 frames per second at full resolution and up to 1 million frames per second at lower resolutions), a gated ICCD camera (capable of single exposures down to 55 nanosecond exposure times) and flash x-ray equipment.

## Energy Research and Development Center (ERDC)

### 110 Engineering Research Laboratory Joseph D. Smith (Director)

The Energy Research and Development Center (ERDC) provides an environment for researchers from various Missouri S&T disciplines to

collaborate on sponsored projects involving energy and its impact on society and the environment. The mission of the ERDC is to educate students in energy topics that address key challenges that face society related to energy issues involving industry and government, for the benefit of the university, the state of Missouri, and the nation. Topics of interest include developing “Hybrid Energy Systems” that combine legacy and renewable energy sources, development of drop-in compatible biofuels, application of alternative energy sources including wind and solar, plug-in hybrid vehicles, the bulk power system, high temperature electrolysis to produce hydrogen, cyber-security of energy management systems, synthetic fuel development, advanced nuclear energy systems such as small modular reactors, and petroleum exploration and extraction methods. More than 41 faculty researchers are affiliated with the Center. Researchers affiliated with the Energy R&D Center also closely collaborate with other research centers including Materials Research Center, Intelligent Systems Center, Center for Infrastructure Engineering Studies, and the Environmental Research Center. For more information visit the web site at <http://energy.mst.edu> or contact [erdc@mst.edu](mailto:erdc@mst.edu).

## Intelligent Systems Center (ISC)

**320 Engineering Research Lab**  
**Donald C. Wunsch (Interim Director)**  
<http://isc.mst.edu>

### Senior Research Investigators

Frank Liou, Sanjay Madria, Bruce McMillin, Jagannathan Sarangapani, Don Wunsch

### Research Investigators

Douglas Bristow, K. Chandrashekhara, Sajal Das, Medhi Ferdowsi, Jonathan Kimball, Robert Landers, Suzanna Long, Anthony Okafor, Sahra Sedigh, Xiaodong Yang, Maciej Zawodniok

### Associate Investigators

Venkat Allada, Ahmad Alsharoa, Rui Bo, Casey Canfield, Steve Corns, Fatih Dogan, Xiangyang Dong, David Enke, Jie Gao, Abhijit Gosavi, Daoru Han, Jie Huang, Xinhua Liang, Sid Nadendla, Heng Pan, Jonghyun Park, Joontaek Park, Ruwen Qin, Pourya Shamsi, Daniel Shank, Yun Seong Song, Haiming Wen

The mission of the Intelligent Systems Center (ISC) is to provide an interdisciplinary research environment in which faculty from various departments can cooperate and conduct research on sponsored projects involving real physical systems with special emphasis on an intelligent (smart) system approach. ISC has integrated its primary research mission with Missouri S&T's commitment to develop internationally recognized graduate research programs focused on key emerging and critical technologies.

The approaches that we are taking to accomplish ISC's objectives are:

- Developing multidisciplinary research programs to address the emphasis areas of federal sponsoring agencies with the expertise of Missouri S&T faculty who are ISC members
- Obtaining both short- and long-term federal research grants and industrial contracts
- Developing advanced research facilities

The education of graduate students is one of ISC's major activities. To this end ISC provides graduate research assistantships to selective graduate students through the Center Members. The interdisciplinary nature of ISC provides an excellent environment for ISC supported students to interact with fellow students from other departments. The students also gain valuable experience in working as a team and acquire oral and written communication and project organization skills. The interaction of graduate students with engineers from industries and program managers from federal agencies is very valuable.

Multidisciplinary research teams consisting of faculty members and graduate students from the departments of computer science, electrical and computer engineering, engineering management and systems engineering, and mechanical and aerospace engineering have been established to conduct research. ISC has also developed state-of-the-art laboratories to conduct research on virtual prototyping, additive manufacturing, smart structures, neural networks, energy systems, automatic inspection, MEMS, robotics, and structural health monitoring. Active research is in significant progress in the following thrust areas:

1. Intelligent Manufacturing Processes, Equipment and Systems
  - 1.1 Virtual Reality and Prototyping
  - 1.2 Additive/Rapid/Direct Digital Manufacturing
  - 1.3 Laser Micromachining
  - 1.4 Friction Stir Processing
  - 1.5 Composite Manufacturing
  - 1.6 Liquid Metal Processing
2. Intelligent Cyber Physical Systems
  - 2.1 Energy Generation Systems
  - 2.2 Power Distribution Systems
  - 2.3 Fuel Cells and Batteries
  - 2.4 Transportation Systems
3. Advanced Simulation, Sensing, Control, and Communication
  - 3.1 Sensors and Sensor Networks
  - 3.2 Intelligent and Adaptive Control
  - 3.3 Communication Systems and Networks
4. Computational Intelligence and Embedded Systems
  - 4.1 Data Processing, Fusion and Management
  - 4.2 Design and System Support
  - 4.3 Trustworthy and Embedded Hybrid Systems
5. Cyber Security and Trustworthiness
  - 5.1 Cloud Systems and Software
  - 5.2 Critical Infrastructure
  - 5.3 Wireless Networks and Big Data Management

## 5.4 Smart Health-Care and Social Systems

## Materials Research Center (MRC)

### Straumanis-James Hall

### William G. Fahrenholtz (Director)

### Senior Investigators

R. Brow (MSE), W. Fahrenholtz (MSE), J. Fan (EE), G. Hilmas (MSE), Y. S. Hor (Physics), X. Liang (Chem E), J. Medvedeva (Physics), R. O'Malley (MSE), J. Switzer (Chem), X. Yang (MAE).

### Research Investigators

L. Alagha (Mining), B. Bai (GE), S. Baura (Chem E), D. Borrok (Geo), D. Bristow (Mech), C. Castano (Nuc), A. Chernatynskiy (Physics), A. Choudhury (Chem), D. Day (MSE), F. Dogan (MSE), M. Elgawady (Civil), I. Ferguson (EE), G. Galecki (Mining), J. Gao (Mech), J. Graham (Nuc), G. Grubbs (Chem), J. Huang (EE), C. Hwang (ECE), A. Imqam (Geo), C.S. Kim (ECE), D.H. Kim (EE), A. Kumar (MSE), S. Lekakh (MSE), F. Liou (Mech), D. Lipke (MSE), M. Locmelis (GE), D. Ludlow (Chem E), H. Ma (Civil), M. Moats (MSE), V. Mochalin (Chem), J. Myers (Civil), M. Nath (Chem), J. Newkirk (MSE), M. O'Keefe (MSE), M. Okoronkwo (Chem E), G. Olgun (Civil), D. Ownby (MSE), H. Pan (Mech), J. Park (Mech), F. Rezaei (CHEM E), A. Rownaghi (Chem E), J. Schlegel (Nuc), T. Schuman (Chem), J. Smith (MSE), L. Sotiriou-Leventis (Chem), R. Wang (Chem), J. Watts (MSE), M. Wei (GE), H. Wen (MSE), J. Winiarz (Chem), C. Wu (Civil), G. Xu (Mining), W. Yang (GE).

The Graduate Center for Materials Research was established for the purpose of promoting multidisciplinary research on materials and providing improved centralized laboratories and specialized equipment for faculty and students involved in materials research. The Center provides graduate students in many academic departments (e.g. Materials Science and Engineering, Chemical and Biological Engineering, Mechanical and Aerospace Engineering, Chemistry, Biological Sciences and Physics) with advanced training in materials related engineering and science research.

The research conducted in the Center ranges from fundamental science to applied engineering and includes the development, evaluation, application, and understanding of metals, polymers, biomaterials, electronic materials, ceramics and composites.

Accomplishments from the Center include: glass microspheres for treatment of liver cancer, transparent composites for windows/armor, environmentally friendly corrosion coatings, laser glasses, epitaxial chiral surfaces, biomineralization, fuel cell electrolytes and sealing materials, electrochemical biosensors, multi-layer nano-capacitors, enhanced magnetic materials, and thin film electromagnetic probes.

The Center is located in Straumanis-James Hall, a four-story building with 30,000 square feet of laboratory and office space. The Center contains the modern equipment needed for research on materials development, characterization and evaluation, and for measuring common mechanical, thermal, electrical, and optical properties. It contains specialized and adaptable experimental facilities for:

- Advanced Structural Ceramics
- Corrosion and Coatings
- Electrodeposition/Photocatalysis
- Electromagnetic Compatibility

- Glass Melting and Processing
- Integrated Computational Materials Engineering (ICME)
- Nanomaterials
- Steels and Metallic Alloys
- Sensors and MEMS Devices
- Characterization of materials by: x-ray diffraction, focused ion beam (FIB) milling, scanning and transmission electron microscopy, scanning tunneling and atomic force microscopy, thermal analysis, optical techniques, x-ray photoelectron spectroscopy, x-ray fluorescence spectroscopy

The Center has an active interest in industrial research and economic development suitable for graduate and undergraduate student education that falls within the technical expertise of the staff.

E-mail [mrc@mst.edu](mailto:mrc@mst.edu) or visit our website at <http://mrc.mst.edu>.

## Rock Mechanics and Explosives Research Center (RMERC)

### Dr. Norbert Maerz (Director)

### Research Investigators

Lana Alagha (MinEng), Neil Anderson, (GeoEng), Kwame Awuah-Offei (MinEng), Baojun Bai (PetEng), Andreas Eckert (PetEng), Grzegorz Galecki (MinEng), Stephen Gao (GeoPhysics), Leslie Gertsch (GeoEng), Abdulmohsin Imqam (PetEng), Catherine Johnson (ExpEng), Hyoungh Lee (NucEng), Jenny Liu (CivEng), Kelly Liu (GeoPhysics), Norbert Maerz (GeoEng), Phillip Mulligan (GeoEng), Guney Olgen (CivEng), Kyle Perry (ExpEng), Taghi Sherizadeh (MinEng), Mingzhen Wei (PetEng), Xiong Zhang (CivEng).

### Staff

Jeff Heniff (Research Engineering Technician II), Fred Eickelmann (Research Engineering Technician I), Stacey Fuller (Administrative Assistant), Fayte Ford (Secretary).

The Rock Mechanics and Explosives Research Center (RMERC) brings together leading investigators from different disciplines to research static and dynamic rock mechanics, rock fragmentation and excavation, and explosives technology. A particular emphasis is to foster innovative and responsive research in rock physics and all fields of science and engineering that deal with rock, including energy production, mining, geology, geophysics, petroleum, nuclear and related fields. The High Pressure Waterjet Laboratory of the RMERC has developed a world-renowned team of waterjet technology specialists. The RMERC has a linear rock cutting machine, compressive testing load frame, and also an array of rotary rock cutting machines, an electronics shop, and a comprehensive machine shop for its students and investigators.

Areas of current research include:

Reagent design for mineral pressing applications, froth flotation, ionic liquids;  
Engineering geophysics, ground penetrating radar, electrical resistivity tomography;  
Modeling, simulation, and optimization for sustainable mining systems;  
Enhanced oil recovery and water management, particle-gels, hydrogel, and nano-fluidics;  
Numerical geomechanics, petroleum related geomechanics modeling;  
Waterjet technology, communication, mineral processing;

Geophysical exploration of the Earth's interior, geophysics, seismology, rock physics;  
Rock mechanics, acoustic emissions, mine hazard prevention and controls, seismic based void detection;  
Space mining, rock excavation, mining method development, mine design;  
Mining health and safety, ground control, underground communications;  
Explosives engineering and technology, explosive taggants, shock physics;  
Geophysical subsurface imaging, seismic interpretation, seismic anisotropy;  
Lidar scanning, landslides, autonomous navigation;  
Energetics, rock dynamics, ground control, coal dust explosion suppression.

E-mail [rockmech@mst.edu](mailto:rockmech@mst.edu) or visit our website at <http://rockmech.mst.edu>.

## SPECIAL FACILITIES AND PROGRAMS

This section contains information about some of the special facilities and programs which graduate students may choose to collaborate or coordinate with during their academic career. Please navigate this section by using the menu at the left and selecting the category that best represents the type of research you wish to view. For more comprehensive information please visit the individual department websites.

### Advanced Materials Characterization Laboratory

**McNutt Hall and Straumanis-James Hall**  
**F. Scott Miller (Director)**  
 smiller@mst.edu  
<http://amcl.mst.edu>

The Advanced Materials Characterization Laboratory was established in 2001 to provide advanced materials characterization instrumentation and expertise to Missouri S&T researchers as well as technological industries in Rolla and the state of Missouri. The laboratory combines advanced analytical resources from several departments on campus, as well as the Materials Research Center to provide a centralized point of contact for researchers.

The characterization equipment available in the AMCL includes: a dual-beam Focused Ion Beam/Scanning Electron microscope instrument, a field emission scanning electron microscope (SEM), and a transmission electron microscope (TEM), all of which are combined with energy dispersive X-ray Spectroscopy (EDS) systems, an e-beam lithography system, two x-ray diffractometers, an x-ray fluorescence analyzer, scanning tunneling and atomic force microscopes, an x-ray photoelectron spectrometer, and instruments for thermal analysis, including thermogravimetric analysis and differential scanning calorimetry.

Training in these methods and assistance in the use of the equipment are provided to faculty researchers, graduate and undergraduate students by the director and staff of the AMCL.

### Center for Aerospace Manufacturing Technologies

**292C Toomey Hall**  
**Douglas A. Bristow (Director)**  
<https://camt.mst.edu>  
**Project Investigators**

Douglas Bristow, K. Chandrashekhara, Ed Kinzel, Frank Liou, Robert Landers, Ming Leu, Joseph Newkirk, David Van Aken

The mission of the Center for Aerospace Manufacturing Technologies (CAMT) is to serve as a center of excellence to research, develop, evaluate and demonstrate new and optimal methodologies and tools for the rapid and cost-effective manufacture of aerospace components and products and to promote new education and training programs for

the evolving aerospace manufacturing workforce, resulting in significant technological advancement and national economic impact.

CAMT was established in May 2004 at Missouri S&T in partnership with Boeing through major funding from the Air Force Research Laboratory in Dayton, Ohio, with the following objectives:

- Research, develop, evaluate, demonstrate and transfer advanced technologies of critical importance to the Air Force and the aerospace supply chain in the United States.
- Create knowledge, methodologies and tools to improve affordability, rapidity, quality, productivity, reliability, and safety in aerospace manufacturing.
- Disseminate the generated results to the aerospace supply chain through direct technology transfer as well as education, training and outreach activities.
- Serve as a role model of university-industry-government collaborative relationship.

CAMT has an array of technologies devoted to advancing manufacturing fabrication and assembly. The interdisciplinary teams, along with advanced equipment and facilities, have created a substantial technology force at Missouri S&T. Realizing the value and importance of CAMT to the entire U.S. aerospace industry, the CAMT Industrial Consortium was established in 2007. Through this, CAMT benefits all consortium members, and its R&D activities are directed by the consortium members.

### Center of Excellence for Aerospace Particulate Emissions Reduction Research

**G34 Shrenk Hall**  
**Philip D. Whitefield, (Director)**  
 pwhite@mst.edu  
<http://coe.mst.edu>

The Missouri S&T COE is a university/industry consortium coordinated by Missouri University of Science and Technology conducting critical research that is providing the tools to characterize, measure, and predict propulsion particulate emissions in current and future aircraft. These tools will be validated both in the field and in realistic laboratory test environments that integrate propulsion altitude cells with state-of-the-art diagnostic systems and numerical modeling, and will be used as much needed consistent standards for current and future engine design by the U.S. and for characterizing the aircraft component of combustion emission in the assessment of local air quality in and around our airports.

The Missouri S&T COE was a founding member and the lead entity for emissions characterization in the Partnership for Air Transportation Noise and Emissions Reduction (PARTNER) a leading aviation cooperative research organization, and a FAA/NASA/Transport Canada/US DoD/US EPA-sponsored Center of Excellence. The Missouri S&T COE is also a founding member and the lead entity for emissions characterization in the Aviation Sustainability CENTER (ASCENT), the new FAA/NASA/Transport Canada/US DOD/US EPA-sponsored Center of Excellence for Alternative Jet Fuels and Environment. Our objectives are to characterize the emissions (both small particles and condensable

gaseous species) from aircraft and airports through measurements, understanding and model the microphysical processes associated with particle formation, and determine the health effects of emissions. The characterization of emissions from aircraft and airports requires comprehensive measurement of small particles and condensable gaseous species. In fact, it requires measurement of both the emissions of individual airplanes as they contribute to the total aircraft segment of the emissions budget of an airport, and the emissions at the fence line of the airport due to all airport operations.

The major tasks of the COE are:

- Analyze and Correlate Particle Concentration Data
- Study quantifying emission indexes
- Develop Field Testing Data

Visit our website at: <http://coe.mst.edu> or e-mail [pwhite@mst.edu](mailto:pwhite@mst.edu). ([pwhite@mst.edu](mailto:pwhite@mst.edu))

## Critical Infrastructure Protection Laboratory

### 308 Computer Science Building Bruce McMillin (Director)

The Critical Infrastructure Protection Laboratory is an organization dedicated to research in advanced methods of secure, distributed and parallel computation. The current focus is on the use of rigorous mathematics through formal methods to create fault-tolerant and secure real-time distributed computing systems applied to critical infrastructure protection. This area is known as Cyber-Physical Systems. The laboratory supports undergraduate, graduate, and faculty researchers.

E-mail us at [ff@mst.edu](mailto:ff@mst.edu) or visit our current cybersecurity website at <http://cae.mst.edu>.

### Design Engineering Center 109 Engineering Management Building Elizabeth A. Cudney (Director)

The Design Engineering Center (DEC) is a unique university research partnership for industry, healthcare, and government. The purpose of the DEC is to address the universal need for effective design, manufacturing, and healthcare methodologies which provide quality educational opportunities to properly prepare and motivate students (undergraduate, graduate, and practicing engineers). The DEC is a research activity in the Engineering Management and Systems Engineering Department. The current organization consists of a director, a number of graduate and undergraduate students, and participating faculty. Current areas of research include quality engineering, healthcare systems engineering, pattern recognition, concurrent engineering, Taguchi Methods®, six sigma and design for six sigma, product development, engineering education, and design optimization. E-mail [cudney@mst.edu](mailto:cudney@mst.edu) or visit <http://emse.mst.edu/research/labs/dec/>.

## Experimental Mine Bridge School Road Dr. Kyle Perry (faculty member responsible)

The Experimental Mine, situated on Bridge School Road 1.5 miles from the main campus, consists of 25 acres of surface and underground facilities which provide excellent opportunities for mineral engineering teaching and research. The surface land includes several dolomite quarries. The underground workings consist of four shafts and approximately 2,000 feet of single-level drifts.

This excellent teaching facility is equipped with a variety of mine-related equipment which offers practical hands-on experience in critical topics. This includes air compressors, rock drills, mucking machines, diamond core drill, blasting seismography, extensometers, machine shop, and surveying instruments. A complete ventilating fan system is connected to the underground area, appropriately installed for experimental data collection. The Kennedy Experimental Mine Building, completed in 2016, houses three classrooms for instruction, laboratory spaces, and offices.

Recent faculty and students research has been conducted in the areas of rock blasting, mine ventilation and atmospheric control, rock mechanics, and explosion effects. The quality of facilities is indicated by the frequency of requests for government and industrial use of the premises. Student projects, however, retain priority on this equipment and the working areas.

E-mail [mining@mst.edu](mailto:mining@mst.edu) or visit our web site at: <http://mining.mst.edu/research/depexpmine/>.

## High Pressure Waterjet Laboratory Rock Mechanics & Explosives Research Center Grzegorz Galecki (Director) [ggalecki@mst.edu](mailto:ggalecki@mst.edu)

State-of-the-art equipment provides support for studying and providing solutions for special needs in manufacturing, mineral processing, nano-materials, and military, aerospace, and environmental industries.

Processes utilizing high pressure waterjets include high-precision waterjet cutting, depth-cut control, surface preparation of steel, titanium and other materials, accelerated excavation, comminution, multi-axis milling in mining and manufacturing, and erosion prevention.

Other topics investigated with the high pressure waterjet include fundamental studies of two- and three-phase flow, the mechanics of fluid jet generation, high speed phenomena, and the physics of fluid impact.

This laboratory is available to serve campus needs. Please call for rates.

For more information please visit our website <http://rockmech.mst.edu/>, call 573-341-4365, or email [ggalecki@mst.edu](mailto:ggalecki@mst.edu).

## Institute for Applied Nuclear Magnetic Resonance (NMR Institute)

### Schrenk Hall Klaus Woelk (Director)

The Institute for Applied Nuclear Magnetic Resonance was established by the Chemistry Department in 1990.

The purpose of this Institute is to provide researchers and scholars access to modern Nuclear Magnetic Resonance (NMR) technology and instrumentation. The Institute specifically assists in the development of modern NMR techniques and procedures that focus on problems relating to applied chemistry and materials science needs. Funding for the NMR Institute supports the operation and maintenance of the Missouri S&T NMR Instrumentation and Laboratories. The NMR instrumentation is multi-disciplinary and is used by many researchers on campus.

Members of the Institute include Dr. R. G. Brow, Dr. A. Choudhury, Dr. A. Convertine, Dr. R. Glaser, Dr. M. Nath, Dr. J. Park, Dr. P. Reddy, Dr. T. Schuman, Dr. C. Sotiriou-Leventis (Co-director), Dr. P. Stavropoulos, Dr. M. Van De Mark, and Dr. K. Woelk (Director)

The Institute promotes the study of materials and chemical solutions with the goal of solving practical problems in the areas of polymers, coatings, solvents, surfactants, thin films, and environmental science. Specific interests and current research projects are related to the properties and behaviors of polymers and biopolymers, coatings, composites, and conducting materials, as well as the discovery and development of new types of materials by use of chemical synthesis. Several researchers are studying the transport and mobility of molecules in porous, colloidal, and macromolecular systems. The structure and dynamics of surfactant-based systems, including micelles, microemulsions, liquid crystals, and colloidal dispersions are studied as well. The development of novel NMR data evaluation routines as well as the analysis of chemical processing methods and the development of nano-structured materials are also of interest.

## Laboratory for Atomic, Molecular and Optical Research

### Physics Michael Schulz (Director)

The Laboratory for Atomic, Molecular and Optical Research is composed of Missouri S&T faculty members performing research in atomic molecular and optical physics. This scientific area is concerned with the few body problem, the structure of atoms and molecules and their interaction with each other, with electromagnetic fields, and with quantum-field effects.

The laboratory provides an environment which enhances this research activity, and which fosters cooperation and collaboration. The laboratory also provides a structure for formal cooperative programs, group funding, and other collective scientific activities.

Basic studies in the atomic, molecular and optical sciences have made major contributions to many of the new technologies that exist today. Laboratory faculty and staff members continue to contribute to the development of advanced concepts in such wide ranging areas as ultrafast laser physics, atomic interaction dynamics for electron, positron,

and ion impact, coherence effects, relativistic quantum-field theory, and atomic processes important in controlled nuclear fusion.

Visit <http://physics.mst.edu> or email [schulz@mst.edu](mailto:schulz@mst.edu).

## Laboratory for Information Technology Evaluation

### Campus Support Building Fiona Nah (Director)

The Laboratory for Information Technology Evaluation's (LITE) mission is to evaluate and explore the impact of information technologies on people, society, organizations, and culture through the utilization of diverse research tools and methodologies. Software and devices allow researchers to study an individual's psychophysiological responses, including facial expressions, eye gaze, skin conductance, and electroencephalographic (EEG) activity. LITE also promotes research and scholarship opportunities, and maintains industry connections, particularly within the Human-Computer Interactions (HCI) and User Experience (UX) field.

For more information, visit <http://lite.mst.edu> or email [nahf@mst.edu](mailto:nahf@mst.edu) ([rhall@mst.edu](mailto:rhall@mst.edu)).

## Mineral Processing Laboratory

### Experimental Mine Building-G5 McNutt Hall –B34&B36

### Lana Alagha, Associate Professor [alaghal@mst.edu](mailto:alaghal@mst.edu)

Mineral processing laboratories (MPLs) are research and education laboratories that serve the needs of mining engineering courses and research at undergraduate and graduate levels. The mission of MPLs is to produce high quality trained mining engineers by providing hands-on laboratory experience and developing practical skills. The practical skills involve basic test techniques for mineral sampling and characterization, mineral classification and physical beneficiation, and basic hydrometallurgy. Graduate students at MS and PhD levels use these facilities to carry on research projects in the field of mineral processing and extractive metallurgy. Mineral processing equipment include bench scale jaw crusher, cone crusher, laboratory ball and rod mills, hydrocyclone classifier, shaking table, spiral concentrator, optical microscope, sieve sets and shakers, mortar grinders, pH meter, analytical balances, vacuum filter, and different bench scale flotation cells. Laboratory equipment also include Zetasizer Nano ZS (Malvern, UK) which is used to measure particle size, translational diffusion, electrophoretic mobility, zeta potential viscosity, and viscoelasticity of mineral suspensions. MPLs serve the needs of the following mining engineering courses:

MI ENG 2412, MI ENG 4412, MI ENG 4212, MI ENG 5423, MI ENG 5424



## Missouri Institute for Computational and Applied Mathematical Sciences

### Rolla Building

#### John R. Singler (Director)

The interweaving of computational sciences and mathematics remains one of the most significant driving forces in the development of science and technology. The institute promotes the development of multidisciplinary research communities engaging applied mathematicians, computational scientists and engineers in innovative research on important scientific and technological problems. In pursuit of its mission, the institute supports research, provides educational opportunities at all levels, and serves as a resource for the state in support of high-technology industrial development.

For more information email [mathstat@mst.edu](mailto:mathstat@mst.edu).

## Missouri S&T Global - St. Louis

### S&T Global-St. Louis Facility

Missouri S&T Global-St. Louis provides graduate programs in various engineering and computer-oriented disciplines. For more than 50 years, S&T Global-St. Louis has been educating some of the best leaders and professionals in the greater St. Louis area. Almost 3,000 S&T students have taken classes through S&T Global-St. Louis to earn their master's degrees. Classes at the St. Louis facility are taught by prominent educators, former deans and department chairs with real-world experience. Lectures are live streamed over the internet, recorded and archived for future review and access. This approach allows students the flexibility of attending classes at the St. Louis facility or joining remotely, whichever fits your schedule. The facility is administered through S&T Global Learning.

For further information, contact:

S&T Global-St. Louis  
West County Continuing Education Center  
12837 Flushing Meadows Dr., Suite 210  
St. Louis, MO 63131  
Phone: 314-835-9822  
Email: [global@mst.edu](mailto:global@mst.edu)

## Rocks Mechanics Laboratory

### Room B-26 & B-28, McNutt Hall

#### Taghi Sherizadeh, Assistant Professor

[sherizadeh@mst.edu](mailto:sherizadeh@mst.edu)

This facility contains several compressive/tensile strength testing machines, including a Terra-Tek computer controlled stiff testing machine rated to 600,000 lbs. These machines are complimented by triaxial cells, strain transducers, load cells and control, data acquisition, computation and hard copy systems. Additional equipment includes ultrasonic pulse velocity test equipment for P and S waves, rock bolt testing equipment including direct shear machine, pull test equipment and instrumentation. The lab also has an Unholtz-Dickie vibration test machine capable of 500 lbs force with a 1" stroke, and SP2000 motion analysis system, and a Rockwell hardness testing machine.

## South Central Regional Professional Development Center

### 1100 W 10th Street, Suite E103 PCRMC Annex

#### Dr. Aaron Zalis (Director)

The South Central Regional Professional Development Center (SCRPDPC) is a part of the statewide system of support for K-12 public school districts. The Center officially serves 63 school districts in the counties of Crawford, Dent, Franklin, Howell, Iron, Maries, Oregon, Phelps, Pulaski, Reynolds, Shannon, Texas, and Washington. As a part of a seamless statewide system of support, services provided by the center are available to surrounding regions as well. The Center's programs and services are available free of charge to students and faculty in the Missouri S&T teacher education program, and are available at cost recovery only to all Missouri S&T faculty and staff.

The mission of SCRPDPC is to "Build the Capacity of Educators through high quality professional learning to maximize student success." The center delivers the following services to educators and leaders throughout the region:

- Implementing effective collaborative teaming processes focused on student learning;
- Collecting, analyzing, and using formative assessment data for decision-making;
- Developing and implementing rigorous student learning targets and learning tasks aligned to Missouri learning standards;
- Developing effective social/behavioral management systems;
- Selecting and implementing research-based highly effective teaching and learning practices;
- Developing and implementing quality formative and summative assessments;
- Developing and supporting effective leaders committed to teacher growth;
- Support for special education improvement and compliance based on research based effective practices;
- Support implementation of best practices relative to literacy development, including services for student with dyslexia;
- Developing and support highly effective teachers focused on implementation of effective instructional practices.

The Center strives to increase the performance of schools throughout the region by providing high quality profession learning with a sustained focus on increasing student learning. This work is delivered both regionally and on-site in schools, is research based, and if implemented with fidelity is designed to positively impact student achievement. In order to accomplish our mission, SCRPDPC organizes and implements workshops, role-alike network groups, study groups, on-going school improvement initiatives, consultation, small and large group facilitation, coaching, observation/feedback, and technical support. The center serves in a leadership capacity for the professional learning throughout the region. Contact us at [rpdpc@mst.edu](mailto:rpdpc@mst.edu), or visit our website at <http://rpdpc.mst.edu>.

## Student Design and Experiential Learning Center

### 116 Kummer Design Center

#### Chris Ramsay (Assistant Vice Provost for Student Design)

##### Learn. Succeed. Have Fun!

Experiential learning is the foundation of a broad-based Missouri S&T education.

The Student Design and Experiential Learning Center (SDLEC) serves as the support center for 20 multi-disciplinary, student-managed design teams.

The SDELC is housed in the Kummer Student Design Center, a facility that provides design team members with advanced computer design labs and software, a complete manufacturing and testing center, business offices and logistical assets, along with the technical, marketing, communication and fundraising support necessary to prepare students for successful careers even before graduation.

Team membership is open to, and encouraged of, S&T students of all academic majors, not just engineering. Team-based learning blends traditional classroom instruction with the critical “outside-the-box” thinking necessary to be successful in a fast-paced development project.

Design team participants enjoy:

- 24-7 facility access
- Strong faculty, staff, business and community support
- Networking opportunities with employers and university competitors
- Specialized training
- Global experience

Visit our website at: [design.mst.edu](http://design.mst.edu) (<http://design.mst.edu/>), call 573-341-7546, or e-mail [sdelc@mst.edu](mailto:sdelc@mst.edu) for more information or to learn how to join a team.

## Technology Transfer and Economic Development

### Suite 145 Technology Development Center at Innovation Park

#### John E. Woodson (Interim Director)

The Office of Technology Transfer and Economic Development (TTED) serves as the focal point for technology commercialization, entrepreneurship, and economic development at Missouri S&T. Its mission is to grow Missouri's economy by advancing technology commercialization, encouraging entrepreneurship, and promoting business opportunities. Located in the Technology Development Center at Innovation Park, TTED manages a variety of programs and initiatives including various programs for students, faculty, and staff.

TTED hosts a Small Business Development Center (SBDC) as part of the Missouri SBDC statewide network. SBDCs are partnerships, primarily between the government and colleges and universities, administered by the United States Small Business Administration. They aim to provide

counseling and educational services for small business owners and aspiring entrepreneurs.

The Student Business Incubator and the VentureLab are programs offered by TTED to support student and community entrepreneurs. The programs operate out of a co-working space in the Technology Development Center at Innovation Park. They provide participants with business counseling, access to work space, conference rooms, and other vital resources to help them develop and successfully launch their businesses ventures. Additional information about these programs can be found at <http://ecodevo.mst.edu>.

One of the primary functions for TTED is managing Missouri S&T's intellectual property portfolio. This includes evaluating the patentability and commercial potential of inventions developed by Missouri S&T faculty researchers, securing intellectual property rights for promising innovations, and commercializing Missouri S&T technologies by licensing them to established businesses and university spinoff companies.

TTED plays an important role in a variety of other important initiatives including the development of Innovation Park (Missouri S&T's 50-acre research park) and managing the Technology Development Center at Innovation Park. For more information about TTED please visit us online at <http://ecodevo.mst.edu>.

## Virtual Surface Mining Simulator

### Room 249, McNutt Hall

#### Samuel Frimpong, Professor and Robert H. Quenon Endowed Chair Frimpong@mst.edu

This facility, the only one of its kind in a university environment, contains physical Dragline and Shovel-Truck Simulators supplied by Immersive Technologies and a Shovel Simulator from Joy Global Inc. within a state-of-the-art technological environment for research and education. These simulators provide virtual environments for simulating heavy machinery in surface mining environments, advanced education and training of heavy mining machinery operators, risks and hazards control and mitigation, planning and deployment of heavy equipment in rugged terrains, and tracking and improving key performance indicators (KPIs).

## Wei-Wen Yu Center for Cold-Formed Steel Structures

### Butler-Carlton Civil Engineering Hall Roger A. LaBoube (Director) Wei-Wen Yu (Founding Director)

To meet an ever-increasing demand for technical assistance from steel and construction industries and to create more economic designs and applications, the Missouri S&T Wei-Wen Yu Center for Cold-Formed Steel Structures (CCFSS) was established to provide an integrated approach for handling research, teaching, and technical services on cold-formed steel structures at Missouri S&T. The Center brings together technical resources from universities, trade associations, research laboratories, steel producers, manufacturing companies, consulting engineers, building officials, governmental agencies, and others.

The Center is currently co-sponsored by the American Iron and Steel Institute, Cold-Formed Steel Engineers Institute, Metal Building Manufacturers Association, Rack Manufacturers Institute, Steel Deck Institute, Steel Framing Industry Association, and the Missouri University of Science & Technology.

Since 1968 Missouri S&T has conducted numerous research projects on cold-formed steel structures. These projects have been supported by the American Iron and Steel Institute, National Science Foundation, the American Society of Civil Engineers, Metal Building Manufacturers Association, Metal Lath/Steel Framing Association, the Steel Deck Institute, the Chromium Centre in South Africa, The Nickel Development Institute in Canada, the Specialty Steel Industry of the United States, and individual companies.

With regard to teaching, Missouri S&T is one of few universities to offer a graduate course on cold-formed steel structures. In addition to the regular course, Missouri S&T has regularly conducted short courses and international specialty conferences to provide continuing education programs for the engineering profession.

# GRADUATE CERTIFICATES

## Graduate Certificate (Discipline)

Actuarial Science (Mathematics and Statistics)  
 Advanced Control Systems (Electrical Engineering)  
 Advanced Engineering Materials (Materials Science and Engineering)  
 AI, Machine Learning and Automation in Business (Information Science & Technology)  
 Applied Workplace Psychology (Psychology)  
 Automation Engineering and PLC (Electrical Engineering)  
 Big Data Management and Analytics (Computer Science)  
 Big Data Management and Security (Computer Science)  
 Business Analytics and Data Science (Information Science & Technology)  
 Business Essentials (Business Administration)  
 Business Intelligence (Information Science & Technology)  
 Business Project Management (Business Administration)  
 CAD/CAM and Rapid Product Realization (Manufacturing Engineering)  
 Composite Materials and Structures (Aerospace Engineering /Mechanical Engineering)  
 Computational Intelligence (Systems Engineering /Computer Engineering /Computer Science)  
 Contemporary Structural Engineering (Civil Engineering)  
 Control Systems (Mechanical Engineering)  
 Cyber Physical Systems (Computer Engineering /Systems Engineering)  
 Cyber Security (Computer Science)  
 Cybersecurity and Information Assurance Management (Information Science & Technology)  
 Digital Media and Web Design (Information Science & Technology)  
 Digital Supply Chain Management (Information Science & Technology)  
 Electric Machine and Drives (Electrical Engineering)  
 Electrical Power Systems Engineering (Electrical Engineering)  
 Electronic and Social Commerce (Information Science & Technology)  
 Energy Conversion and Transport (Aerospace Engineering /Mechanical Engineering)  
 Engineering Management (Engineering Management)  
 Engineering Mechanics (Mechanical Engineering)  
 Enterprise Resource Planning (Information Science & Technology)  
 Entrepreneurship & Technological Innovation (Business Administration)  
 Explosives Engineering (Explosives Engineering)  
 Explosives Technology (Explosives Engineering)  
 Finance (Business Administration)  
 Financial Engineering (Engineering Management /Systems Engineering)  
 Financial Mathematics (Mathematics)  
 Financial Technology (Business Administration)  
 Geoanalytics and Geointelligence (Geological Engineering)  
 Geoenvironmental Engineering (Civil Engineering)  
 Geoenvironmental Science and Engineering (Geological Engineering /Geology and Geophysics)  
 Geologic Hazards (Geological Engineering)  
 Geophysics (Geology and Geophysics)  
 Geotechnical Earthquake Engineering (Civil Engineering)  
 Geotechnics (Geotechnics)  
 Human-Computer Interaction and User Experience (Information Science & Technology)  
 Human Systems Integration (Engineering Management /Information Science & Technology)  
 Information Assurance and Security Officer Essentials (Computer Engineering /Computer Science)  
 Information System Project Management (Information Science & Technology)

Information Systems and Cloud Computing (Computer Science)  
 Infrastructure Renewal (Civil Engineering)  
 Iron and Steel Metallurgy (Metallurgical Engineering)  
 Lean Six Sigma (Engineering Management)  
 Management and Leadership (Business Administration)  
 Management for Sustainable Business (Economics)  
 Manufacturing Automation (Mechanical Engineering)  
 Manufacturing Systems (Manufacturing Engineering)  
 Materials for Extreme Environments (Materials Science and Engineering)  
 Military Construction Management (Engineering Management)  
 Military Geological Engineering (Geological Engineering)  
 Mining Engineering (Mining Engineering)  
 Mobile Business and Technology (Information Science & Technology)  
 Model Based Systems Engineering (Systems Engineering)  
 Nuclear Nonproliferation (Nuclear Engineering)  
 Petroleum Systems (Geology and Geophysics)  
 Project Engineering & Construction Mgmt (Civil Engineering /Engineering Management)  
 Project Management (Engineering Management)  
 Safety Engineering (Chemical and Biochemical Engineering /Engineering Management)  
 Software Design and Development (Computer Science)  
 Space Resources (Geological Engineering)  
 Statistical Methods in Psychology (Mathematics and Statistics / Psychology)  
 Statistics (Mathematics and Statistics)  
 Subsurface Water Resources (Geological Engineering)  
 Systems and Software Architecture (Computer Science)  
 Systems Engineering (Systems Engineering)  
 Technical Communication (Technical Communication)  
 Wireless Networks and Mobile Systems (Computer Science)

The Provost is responsible for the administration of all graduate work at Missouri S&T. In cases where your program can be demonstrably improved, the Provost can approve departures from the graduate faculty rules. Each department may have its own rules beyond the general ones listed and should be contacted if further information is desired at: <http://grad.mst.edu/>.

# GRADUATE DEGREE PROGRAMS

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The Missouri University of Science and Technology offers master of engineering (ME), master of science (MS), master of arts (MA, available as a cooperative degree program with the corresponding departments of the University of Missouri-St. Louis; a maximum of 12 graduate semester hours may be taken at Missouri S&T), master of science for teachers (MST), master of business administration (MBA), doctor of philosophy (PhD), and doctor of engineering (DE) degrees. Missouri S&T also offers two graduate minors (MI). Studies fall into the general areas of business, economics, engineering, English, science and technology.

AEROSPACE ENGINEERING (MS, PhD)

APPLIED MATHEMATICS (MS)

Biological Science (MS)

BUSINESS ADMINISTRATION (MBA)

CERAMIC ENGINEERING (MS, PhD)

CHEMICAL ENGINEERING (MS, PhD, DE)

CHEMISTRY (MS, MST, PhD)

CIVIL ENGINEERING (MS, PhD, DE)

COMPUTER ENGINEERING (MS, PhD)

COMPUTER SCIENCE (MS, PhD)

ECONOMICS (MA)

ELECTRICAL ENGINEERING (MS, PhD, DE)

ENGINEERING MANAGEMENT (MS, PhD)

ENGLISH (MA)

ENVIRONMENTAL ENGINEERING (MS)

EXPLOSIVES ENGINEERING (MS, PhD) MI

EXPLOSIVES TECHNOLOGY (MS)

GEOLOGICAL ENGINEERING (MS, PhD, DE)

GEOLOGY AND GEOPHYSICS (MS, PhD)

GEOTECHNICS (ME)

INDUSTRIAL ORGANIZATIONAL PSYCHOLOGY (MS)

INFORMATION SCIENCE & TECHNOLOGY (MS)

MANUFACTURING ENGINEERING (MS, ME)

MATERIALS SCIENCE AND ENGINEERING (MS, PhD)

MATHEMATICS (MST, PhD)

MECHANICAL ENGINEERING (MS, PhD, DE)

METALLURGICAL ENGINEERING (MS, PhD)

MINING ENGINEERING (MS, ME, PhD, DE)

NUCLEAR ENGINEERING (MS, PhD, DE)

PETROLEUM ENGINEERING (MS, PhD, DE)

PHYSICS (MS, MST, PhD)

SYSTEMS ENGINEERING (MS, PhD)

TECHNICAL COMMUNICATION (MS) MI

## Aerospace Engineering

The aerospace engineering program in the department of mechanical and aerospace engineering offers comprehensive graduate education in a number of areas. Aerodynamics, gas dynamics, hypersonics, aerospace system design, aerospace propulsion, aerospace structures, plasma aerospace applications, multidisciplinary optimization, and flight dynamics and control are the major areas of emphasis. A wide variety of interdisciplinary programs meeting specific objectives are available. The aerospace engineering program offers the master of science and doctor of philosophy degrees. The department also offers several graduate certificate programs in both aerospace engineering and mechanical engineering. Details of certificate programs can be found under the mechanical engineering program listing.

Typical examples of research activities are: analysis and design of composite structures, structural acoustics, aeroacoustics, smart structures, active and passive vibration control, optimization of systems based on structural dynamics or structural performance, astrodynamics, guidance and control of aircraft and missiles, robust multivariable control, microsatellite design, fabrication, and test, neural network architecture for control, estimation theory, real-time flight simulation, non-equilibrium shock wave structure, propulsion research with emphasis on how fuel variables influence combustion, atomization of liquid fuels in supersonic flow, flame stability in combustion systems, scramjet and supersonic combustion scramjet studies, computational fluid dynamics, laser interaction problems, free turbulent mixing, unsteady high angle of attack flow configurations, computer simulation of separated flows, low-speed and high-speed aerodynamics, aerodynamics of high-lift devices, aerospace system design, and viscous effects in transonic flows.

The mechanical and aerospace engineering department has many well equipped laboratories located on the main campus, and a subsonic-flow laboratory in an off-campus facility. Some of the specially equipped laboratories on campus include: a supersonic-flow laboratory with a Mach 4 blow-down wind tunnel, a hot-wire anemometer system, a Schlieren system; an airflow test facility; an acoustics and vibration laboratory; a laser diagnostics laboratory equipped with state-of-the-art lasers to conduct experiments related to aerodynamics and combustion; a composite materials testing laboratory with state-of-the-art material testing system; low velocity impact facility and high speed photography equipment; and extensive computer facilities including a personal computer laboratory, advanced computer graphics laboratory, computer learning center with engineering work stations. The flight simulator program at Missouri S&T incorporates a fixed-base real-time flight simulator without-the-window display.

The master of science thesis program consists of a minimum of 30 credit hours, including the following requirements: at least 21 credit hours of lecture courses, at least 6 credit hours of MECH ENG 6099, at least 9 credit hours of lecture courses in the MAE department (of

which at least 3 credit hours must be at the 6000-level), at least 3 credit hours of mathematics, statistics, or computer science (AERO ENG 5830 Applied Computational Methods may be used to satisfy this requirement), and at least 6 credit hours of 6000-level lecture courses. A master of science non-thesis program consists of a minimum of 30 credit hours, including the following requirements: at least 24 credit hours in the MAE department and at least 9 credit hours of 6000-level lecture courses (of which at least 6 credit hours must be in the MAE department). Note that no course below the 5000-level may be applied to the degree requirements.

A student holding an M.S. degree and pursuing the doctor of philosophy degree must complete at least 60 total credit hours, including the following requirements: at least 24 credit hours of lecture courses, at least 36 credit hours of MECH ENG 6099, at least 12 credit hours of course work in the MAE department, at least 3 credit hours of mathematics, statistics, or computer science (AERO ENG 5830 Applied Computational Methods may be used to satisfy this requirement), and at least 9 credit hours of 6000-level courses (of which at least 6 credit hours must be in the MAE department). In addition to these course requirements, a candidate must prepare a dissertation based on analytical, numerical, and/or experimental research. Note that no course below the 5000-level level may be applied to the degree requirements.

A student holding a B.S. degree and pursuing the direct doctor of philosophy degree must complete at least 90 total credit hours, including the following requirements: at least 45 credit hours of lecture courses, at least 45 credit hours of MECH ENG 6099, at least 21 credit hours of course work in the MAE department, at least 6 credit hours of mathematics, statistics, or computer science (AERO ENG 5830 Applied Computational Methods may be used to satisfy three credit hours of this requirement), and at least 15 credit hours of 6000-level courses (of which at least 9 credit hours must be in the MAE department). In addition to these course requirements, a candidate must prepare a dissertation based on analytical, numerical, and/or experimental research. Note that no course below the 5000-level level may be applied to the degree requirements.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The candidate is considered to have passed the qualifying examination if the candidate has taken at least four courses and has a GPA  $\geq 3.5$  at the end of the candidate's fourth semester. At least two courses must be in the MAE department, one of which must be at the 6000-level.

**S N Balakrishnan**, Curators Distinguished Professor  
PHD University of Texas Austin

Control of aerospace and mechanical systems, flight and orbital mechanics, optimization identification and estimation, numerical methods and stochastic processes, neural networks, wavelets.

**Victor Birman**, Emeritus Professor  
PHD Technion, Haifa, Israel

Director Engineering Education Center in St. Louis. Composite material structures, smart structures.

**K Chandrashekhara**, Curators Distinguished Professor  
PHD Virginia Polytechnic Institute

Composite materials, smart structures, structural dynamics, finite element analysis, composite manufacturing and experimental characterization.

**L R Dharani**, Curators Distinguished Professor  
PHD Clemson University

Curators' Professor of Engineering Mechanics and Aerospace Engineering and Senior Investigator in Graduate Center for Materials Research. Micromechanics of bi-material interfaces, composite materials, fracture mechanics, fatigue and failure analysis of welded structures, wear and friction in composites, fracture and failure of laminated glass.

**Walter Eversman**, Curators Distinguished Professor Emeritus<sup>1</sup>  
PHD Stanford University

Noise control, acoustics, vibrations, aircraft structural dynamics and aeroelasticity, systems and control.

**Daoru Han**, Assistant Professor

PHD University of Southern California

Plasma aerospace applications; space propulsion; plasma-material interactions; plasma physics and rarefied gas dynamics; high-performance computing.

**Serhat Hosder**, Professor

PHD Virginia Polytechnic Institute

Computational fluid dynamics, aerodynamics, multidisciplinary design and optimization, uncertainty and error quantification in computational simulations, robust design, micro/nano flows, hypersonic flows, numerical methods.

**K M Isaac**, Professor

PHD Virginia Polytechnic Institute

Associate Chair for Aerospace Engineering. Fluid dynamics and combustion, aero-structure interaction and control, intelligent aircraft, active flow control, wave-riders, microfluidics, MEMS, flow and combustion in porous media, multiphase flow, emissions from combustion and evaporative systems, lean premixed combustion, combustion instability, active 116 - Graduate Faculty combustion control, atomization and sprays, particle image velocimetry (PIV) and CFD applications in fluid dynamics and combustion problems.

**Gearoid P MacSithigh**, Associate Professor Emeritus

PHD University of Minnesota

Finite elasticity, viscoelasticity, liquid crystal hydrodynamics, solid and continuum mechanics.

**Henry J Pernicka**, Professor

PHD Purdue University

Astrodynamics, orbital mechanics, spacecraft design, spacecraft mission design, satellite attitude dynamics, nonlinear analysis, dynamics and control, optimization.

**David W Riggins**, Curators Distinguished Teaching Professor

PHD Virginia Polytechnic Institute

Fluid dynamics, computational fluid dynamics, hyper/sonic propulsion systems, computational analysis of jet mixing, flow losses and mixing enhancement in combustors, aircraft gas turbine scramjet propulsion systems, and scramjet performance.

**AERO ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**AERO ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Mech Eng 5001).

**AERO ENG 5131 Intermediate Thermofluid Mechanics** (LEC 3.0)

Derivation of Navier-Stokes equations, analytical solutions of viscous flows; flow in pipes, flow networks; intermediate treatment of boundary layer theory; micro-fluidics and MEMS; introduction to numerical methods for solving fluid flows; and, preliminary treatise on turbulence. Prerequisite: Mech Eng 3131 or Aero Eng 3131. (Co-listed with Mech Eng 5131).

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**AERO ENG 5139 Computational Fluid Dynamics** (LEC 3.0)

Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Comp Sci 1570 or 1970 or 1971; one course in fluid mechanics. (Co-listed with Mech Eng 5139).

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**AERO ENG 5169 Introduction to Hypersonic Flow** (LEC 3.0)

A study of the basic principles of hypersonic flow. Inviscid and viscous hypersonic flow. Application of numerical methods. High temperature flow. Consideration of real gas and rarefied flow. Applications in aerodynamic heating and atmospheric entry. Prerequisites: Aero Eng 3171.

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**AERO ENG 5171 V/Stol Aerodynamics** (LEC 3.0)

Basic concepts of V/STOL flight. Take-off transition and landing performance, thrust vectoring. Propeller and helicopter aerodynamics. Unblown and blown flaps. Boundary layer control. Lift fans and ducted propellers. Wing-propeller interaction and thrust augmentation. Prerequisite: Aero Eng 3171.

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**AERO ENG 5212 Introduction to Finite Element Analysis** (LEC 3.0)

Variational formulation of the governing equations. Finite element model, interpolation functions, numerical integration, assembly of elements and solution procedures. Applications to solid mechanics, fluid mechanics and heat transfer problems. Two-dimensional problems. Computer implementation and use of commercial finite element codes. Prerequisites: Math 3304; senior or graduate standing. (Co-listed with Mech Eng 5212).

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**AERO ENG 5220 Advanced Mechanics of Materials** (LEC 3.0)

Comprehensive insight into mechanics of materials. Topics to include: theories of failure, torsion of noncircular sections, shear flow and shear center, unsymmetric bending, bending of curved members, beams on elastic foundation and pressurization of thick walled cylinders. Prerequisites: Civ Eng 2210, Math 3304. (Co-listed with Mech Eng 5220).

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**AERO ENG 5222 Introduction to Solid Mechanics** (LEC 3.0)

Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: Eng Mech 5211. (Co-listed with Mech Eng 5222).

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**AERO ENG 5229 Smart Materials and Sensors** (LAB 1.0 and LEC 2.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Mech Eng 5229, Elec Eng 5270 and Civ Eng 5118).

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**AERO ENG 5234 Stability of Engineering Structures** (LEC 3.0)

Solution of stability problems with applications to columns, plates and shell structures. Torsional and lateral buckling of columns. Buckling under high temperatures. Effect of imperfections introduced by a technological process on stability. Design issues related to stability requirements. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Mech Eng 5234).

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**AERO ENG 5236 Fracture Mechanics** (LEC 3.0)

Linear elastic and plastic mathematical models for stresses around cracks; concept of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5236).

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**AERO ENG 5238 Fatigue Analysis** (LEC 3.0)

The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints components and structures, design to prevent fatigue. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5238).

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**AERO ENG 5282 Introduction to Composite Materials & Structures** (LEC 3.0)

Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5282).

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**AERO ENG 5307 Vibrations I** (LEC 3.0)

Equations of motion, free and forced vibration of single degree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studied. The vibration of continuous systems is introduced. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Mech Eng 5307).

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**AERO ENG 5309 Engineering Acoustics I** (LEC 3.0)

Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mech Eng 3411 & 3313, or Aero Eng 3613 & Math 3304. (Co-listed with Mech Eng 5309).

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**AERO ENG 5313 Intermediate Dynamics of Mechanical and Aerospace Systems** (LEC 3.0)

Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: Mech Eng 3313 or Aero Eng 3613. (Co-listed with Mech Eng 5313).

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**AERO ENG 5353 Aeroelasticity** (LEC 3.0)

Study of phenomena involving interactions among inertial, aerodynamic, and elastic forces and the influence of these interactions on aircraft and space vehicle design. Some aeroelastic phenomena are: divergence, control effectiveness, control reversal, flutter, buffeting, dynamic response to rapidly applied loads, aeroelastic effects on load distribution, and static and dynamic stability. Prerequisites: Aero Eng 3251 and 3171.

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**AERO ENG 5361 Flight Dynamics-Stability And Control** (LEC 3.0)

Review of static stability, dynamic equations of motion, linearized solutions, classical control design and analysis techniques, introduction to modern control. Prerequisite: Aero Eng 3361.

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**AERO ENG 5449 Robotic Manipulators and Mechanisms** (LEC 2.0 and LAB 1.0)

Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Mech Eng 3313; Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972 or Comp Sci 1570. (Co-listed with Mech Eng 5449).

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**AERO ENG 5478 Mechatronics** (LEC 2.0 and LAB 1.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Elec Eng 5870 and Comp Eng 5820).

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**AERO ENG 5481 Mechanical and Aerospace Control Systems** (LEC 3.0)

Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mech Eng 4479 or Aero Eng 3361. (Co-listed with Mech Eng 5481).

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**AERO ENG 5519 Advanced Thermodynamics** (LEC 3.0)

After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Mech Eng 2519. (Co-listed with Mech Eng 5519).

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**AERO ENG 5525 Intermediate Heat Transfer** (LEC 3.0)

Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mech Eng 3525. (Co-listed with Mech Eng 5525).

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**AERO ENG 5527 Combustion Processes** (LEC 3.0)

Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mech Eng 3521. (Co-listed with Mech Eng 5527).

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**AERO ENG 5535 Aerospace Propulsion Systems** (LEC 3.0)

Study of atmospheric and space propulsion systems with emphasis on topics of particular current interest. Mission analysis in space as it affects the propulsion system. Power generation in space including direct and indirect energy conversion schemes. Prerequisite: Aero Eng 4535.

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**AERO ENG 5570 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Mech Eng 5570, Nuc Eng 4370, Physics 4543).

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**AERO ENG 5614 Spaceflight Mechanics** (LEC 3.0)

Further topics in orbital mechanics. Time equations, Lambert's problem, patched-conic method, orbital maneuvers, orbit determination, orbit design, re-entry problem. Prerequisite: Aero Eng 3613.

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**AERO ENG 5715 Concurrent Engineering** (LEC 3.0)

Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mech Eng 3313 or Aero Eng 3131 and Civ Eng 2210 (Co-listed with Mech Eng 5715).

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**AERO ENG 5758 Integrated Product Development** (LEC 2.0 and LAB 1.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, cost, and product support. Using a 3-D solid modeling program, students will design, analyze, and send the data base to the automated machine shop where the parts will be manufactured. The parts will then be assembled, tested and analyzed for their performance. Prerequisites: Aero Eng 3251 or Mech Eng 3708 for Design; Mech Eng 3313 for Assembly; Accompanied or preceded by Mech Eng 5653 for Manufacturing; Eng Mgt 5711 or 5714 for Cost/Product Support.

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**AERO ENG 5760 Probabilistic Engineering Design** (LEC 3.0)

The course deals with uncertainties in engineering analysis and design at three levels - uncertainty modeling, uncertainty analysis, and design under uncertainty. It covers physics-based reliability analysis and reliability-based design, robustness assessment and robust design, their integration with design simulations, and their engineering applications. Prerequisite: Mech Eng 3708 or Aero Eng 3361. (Co-listed with Mech Eng 5760).

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**AERO ENG 5830 Applied Computational Methods** (LEC 3.0)

Detailed study of computational methods for efficient solution of selected fluids, structures, thermodynamics, and controls problems in aerospace and mechanical engineering. Besides basic numerical techniques, topics covered include gradient-based optimization and uncertainty quantification. Prerequisite: Comp Sci 1570 or 1970 or 1981; Math 3304. (Co-listed with Mech Eng 5830).

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**AERO ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects of projects in the department. Consent of instructor required.

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**AERO ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Mech Eng 5001).

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**AERO ENG 6010 Seminar** (LEC 0.0-1.0)

Discussion of current topics. (Co-listed with Mech Eng 6010).

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**AERO ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**AERO ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**AERO ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**AERO ENG 6123 Viscous Fluid Flow** (LEC 3.0)

Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; boundary layer theory for incompressible and compressible flows; stability and transition. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Mech Eng 6123).

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**AERO ENG 6131 Gas Dynamics I** (LEC 3.0)

A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandtl-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Mech Eng 6131).

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**AERO ENG 6135 Turbulent Flows - Theory, Measurements and Modeling** (LEC 3.0)

Navier-Stokes equations; statistical description and mean-flow equations; behavior of free shear and wall bounded flows; the energy cascade; turbulence spectra and Kolmogorov hypothesis; measurement techniques: PIV, hot-wires, LDV; turbulence modeling for transport processes and closure schemes for RANS equations; evaluation of model constants, introduction to LES, DNS and hybrid-RANS. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Mech Eng 6135).

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**AERO ENG 6137 Physical Gas Dynamics I** (LEC 3.0)

Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and Nonequilibrium gas properties and gas flows are included. Prerequisite: Mech Eng 5131 or Aero Eng 5131. (Co-listed with Mech Eng 6137).

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**AERO ENG 6212 Advanced Finite Element Analysis** (LEC 3.0)

Higher order, isoparametric and mixed finite elements. Eigenvalue and time-dependent problems. Solution procedures for dynamic analysis. Implicit and explicit methods. Applications to viscous incompressible fluid and plate bending problems. Three-dimensional problems. Nonlinear finite element analysis. Practical applications using commercial software. Prerequisite: Mech Eng 5212 or Aero Eng 5212. (Co-listed with Mech Eng 6212).

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**AERO ENG 6222 Theory of Elasticity** (LEC 3.0)

Formulation and study of boundary-value problems in 2-D linear elastostatics: Equilibrium and compatibility. Stress function formulations in Cartesian and polar coordinates. Curved beam, wedge and plane contact problems. Dislocations and cracks. Thermoelasticity. Prerequisites: Civ Eng 2210. (Co-listed with Mech Eng 6222).

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**AERO ENG 6284 Analysis of Laminated Composite Structures** (LEC 3.0)

An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Mech Eng 6284).

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**AERO ENG 6285 Mechanics Of Composite Materials** (LEC 3.0)

Effective moduli of spherical, cylindrical and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear lag and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Mech Eng 6285).

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**AERO ENG 6307 Advanced Vibrations** (LEC 3.0)

Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems and random excitations. Prerequisite: Mech Eng or Aero Eng 5307. (Co-listed with Mech Eng 6307).

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**AERO ENG 6313 Advanced Aerospace Mechanics** (LEC 3.0)

Current problems in aerospace dynamics are treated using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations, stability of systems, to include approximate techniques. Prerequisite: Mech Eng or Aero Eng 5313. (Co-listed with Mech Eng 6313).

**AERO ENG 6447 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Eng Mgt 6410, Sys Eng 6217 and Comp Sci 6202).

**AERO ENG 6458 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Mech Eng 6458 and Sys Eng 6215).

**AERO ENG 6479 Analysis And Synthesis Of Mechanical And Aerospace Systems** (LEC 3.0)

A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mech Eng 5481 or Aero Eng 5481. (Co-listed with Mech Eng 6479).

**AERO ENG 6481 Advanced Topics in Decision and Control** (LEC 3.0)

This course will deal with latest topics in the areas of decision and control. Course may be repeated if topics vary. Prerequisites: Aero Eng 5481 or Mech Eng 5481 or equivalent. (Co-listed with Mech Eng 6481).

**AERO ENG 6525 Heat Transfer by Conduction** (LEC 3.0)

A study of conduction of heat transfer in solids by analytical and other methods. Prerequisite: Mech Eng 5525 or Aero Eng 5525. (Co-listed with Mech Eng 6525).

**AERO ENG 6527 Heat Transfer by Convection** (LEC 3.0)

An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current topics in convection. Prerequisite: Mech Eng 5525 or Aero Eng 5525. (Co-listed with Mech Eng 6527).

**AERO ENG 6529 Heat Transfer by Radiation** (LEC 3.0)

A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Mech Eng 6529).

**AERO ENG 6614 Advanced Astrodynamic** (LEC 3.0)

Analysis of spacecraft motion using different dynamic models and perturbations. Using the state transition matrix and differential corrections technique for trajectory computation. Introduction to the three-body problem. Use of computational and numerical methods to solve astrodynamic problems. Prerequisite: Aero Eng 5614.

## Biological Sciences

The department of biological sciences offers a thesis and a non-thesis M.S. degree track for students who want to pursue graduate education.

A graduate degree in biological sciences allows students to enhance their career marketability and further their education. As part of a science and technology university, our program has the unique advantage of being part of a rich history of scientific application that includes patent development, deep connections with the leading scientific and technological industries, and innovative solutions to challenging global problems.

Graduate students in the department work closely with faculty advisors and other students to design, execute, and interpret experiments that answer basic and applied scientific questions. We encourage interdisciplinary and transdisciplinary collaborations, external partnerships, and participation in regional and national conferences. Competitively awarded graduate teaching assistantships are available for excellent applicants with an identified faculty mentor.

## Equipment and Facilities

In the department of biological sciences, we have access to and utilize an array of cutting-edge technologies for microscopy, genetic analyses, cytology, molecular biology, and microbiology. Our environmental and ecological students utilize the outdoor laboratory at the Missouri S&T Ozark Research Field Station, abundant local natural resources, and our connections with federal and state land management agencies to answer questions related to environmental physiology, hydrological flow, evolutionary origins, and ecological function. The 1,780 square foot Missouri S&T Animal Research Facility houses research animals, colony rooms, and a surgical theater for experimental research in physiology, anatomy, behavior, and medical applications. Departmental offices and laboratories are housed in Schrenk Hall.

## Course Study

### Degree Requirements M.S. - with thesis

BIO SCI 6202	Problems In Applied And Environmental Biology
BIO SCI 5010	Graduate Seminar
BIO SCI 5099	Graduate Research
BIO SCI 6223	Research Proposal Writing

### Degree Requirements M.S. - without thesis

BIO SCI 6202	Problems In Applied And Environmental Biology
BIO SCI 5010	Graduate Seminar

Elective courses are chosen with guidance from the advisor and advisory committee. A minimum of 30 credit hours is required for a M.S. degree. Up to 6 credit hours may be taken at the 3000-level in courses offered by other departments. Candidates for the M.S. degree with thesis conduct original research that is defended in a final oral examination. Non-thesis M.S. degree candidates take a comprehensive written final examination.

**David Duvernell**, Professor  
PHD Virginia Tech  
Population genetics, evolutionary ecology.

**Ronald L Frank**, Chancellors Professor  
PHD Ohio State University  
Molecular genetics, molecular biology.

**Chen Hou**, Associate Professor  
PHD University of Missouri-Columbia  
Metabolic basis of aging, energetic basis of animal growth and reproduction.

**Yue-Wern Huang**, Professor  
PHD University of Wisconsin Madison  
Toxicology, nanobiotechnology, biomedical science.

**Jinling Liu**, Assistant Professor  
PHD The Pennsylvania State University  
Big data analytics, machine learning, biomedical informatics.

**Melanie R Mormile**, Professor  
PHD University of Oklahoma, Norman  
Environmental microbiology.

**Dev K. Niyogi**, Associate Professor  
PHD University of Colorado Boulder  
Ecology, limnology.

**Julie A Semon**, Assistant Professor  
PHD Tulane University  
Adult stem cells, tissue engineering.

**Katie B Shannon**, Teaching Professor  
PHD Harvard Medical School  
Cell biology, mitosis, cytokinesis, cell cycle regulation.

**Matthew Scott Thimgan**, Associate Professor  
PHD The University of North Carolina at Chapel Hill  
Biochemistry, genetics and anatomy of the sleep-loss response, sleep biomarkers.

**Robin Verble**, Associate Professor  
PHD University of Arkansas-Little Rock  
Fire ecology, entomology, fire adapted ecosystems and organisms.

**David J Westenberg**, Associate Professor  
PHD University of California-Los Angeles  
Molecular microbiology, microbial diversity, microbial physiology.

**BIO SCI 5000 Special Problems** (IND 0.0-6.0)  
Graduate problems or readings on specific subjects or projects in the department. Prerequisite: Consent of the instructor.

**BIO SCI 5001 Special Topics** (LEC 0.0 and LAB 0.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**BIO SCI 5010 Graduate Seminar** (RSD 0.0-6.0)  
Presentation and discussion of current topics in Applied and Environmental Biology.

**BIO SCI 5040 Oral Examination** (IND 0.0)  
(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./PH.D students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**BIO SCI 5099 Graduate Research** (IND 0.0-15)  
Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

**BIO SCI 5210 Biomaterials I** (LEC 3.0)  
This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisite: Senior undergraduate standing. (Co-listed with Chem Eng 5200, MS&E 5310).

**BIO SCI 5240 Tissue Engineering** (LEC 3.0)  
The course will use problem-based case studies to introduce junior and senior undergraduate students to the principles and clinical applications of tissue engineering. Topics include the use of biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. Prerequisite: Junior or Senior standing. (Co-listed with MS&E 5210).

**BIO SCI 5313 Pathogenic Microbiology** (LEC 3.0)  
A study of medically important microorganisms. Students will learn about the properties that enable organisms to cause disease as well as the disease process within the host. Special emphasis will be placed on recent advances in the molecular genetics of host pathogen interaction. Prerequisite: Bio Sci 2213 or Civ Eng 2601.

**BIO SCI 5323 Bioinformatics** (LEC 3.0)  
The course will familiarize students with the application of computational methods to biology, as viewed from both perspectives. It will introduce problems in molecular, structural, morphological, and biodiversity informatics, and will discuss principles, algorithms, and software to address them. Prerequisites: A grade of "C" or better in both one of Bio Sci 1113 or Bio Sci 1213 and one of Comp Sci 1570 and Comp Sci 1580 or Comp Sci 1971 and Comp Sci 1981. (Co-listed with COMP SCI 5700).

**BIO SCI 5343 Biology of Aging** (LEC 3.0)  
We will discuss the proximate and ultimate mechanisms of aging, and review a few leading theories of aging with the emphases on oxidative stress and life history tradeoffs. We will take the comparative approach to study aging across species, and the interventions that extend animals' lifespan, and explore why they may or may not work on humans. Prerequisites: Bio Sci 2213.

**BIO SCI 5353 Developmental Biology** (LEC 3.0)  
Study of the patterns of development of the vertebrate embryo, the molecular mechanisms of tissue induction, and interactions among developing tissues. Prerequisite: Bio Sci 2213.

**BIO SCI 5423 Advanced Biodiversity** (LEC 3.0)

This course focuses on the enhancement and reduction of biodiversity and modern techniques of measuring and monitoring it. Topics include biogeography, community structure, competition, predation, food webs, geology-biology relationships, environmental change, and human impact. Additional costs and a week-long field trip are required. Prerequisite: Bio Sci 2233 or Bio Sci 2263.

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**BIO SCI 5533 Pharmacology** (LEC 3.0)

The basic principles of drug action, pharmacokinetics, pharmacodynamics and toxicity. We will emphasize the actions of drugs used to treat cardiovascular and nervous system disorders. Students will review the primary literature to prepare both written and oral reports on drug actions. Prerequisite: Bio Sci 2213.

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**BIO SCI 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**BIO SCI 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**BIO SCI 6202 Problems In Applied And Environmental Biology** (LEC 0.0-3.0)

Overview of major areas of research in applied biology and environmental science with a focus on interdisciplinary approaches used on S&T campus in ongoing research. Prerequisite: Acceptance to Graduate Program.

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**BIO SCI 6210 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. Prerequisite: Graduate Standing. (Co-listed with CHEM ENG 6300, MS&E 6310).

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**BIO SCI 6223 Research Proposal Writing** (LEC 3.0)

Students will learn best practices of grant proposal writing. Students will conduct background research, prepare an annotated bibliography, brainstorm specific aims, and critique each other's writing. The course will conclude with a presentation by the student of their finished proposal. Prerequisites: Graduate standing.

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**BIO SCI 6240 Advanced Tissue Engineering** (LEC 3.0)

The course will introduce graduate students to the principles and clinical applications of tissue engineering including the use biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. A related topic term paper and oral presentation are expected. Prerequisite: Graduate standing. Prerequisite: Graduate standing. (Co-listed with MS&E 6210).

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**BIO SCI 6273 Techniques In Applied And Environmental Biology** (LEC 3.0)

Students will have the opportunity for hands on experience with the various techniques used in the modern biology laboratory. Techniques will include gene cloning, DNA sequencing, protein purification, growth and development of various model organisms, data acquisition. Prerequisite: Graduate standing.

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**BIO SCI 6313 Environmental Microbiology** (LEC 3.0)

Topics to be explored in this course will include but are not limited to microbial growth and metabolic kinetics, life in extreme conditions, biogeochemical cycling, bioremediation of contaminants, waterborne pathogens and environmental biotechnology. Prerequisite: Must be a graduate student.

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**BIO SCI 6343 Advanced Geomicrobiology** (LEC 3.0)

Microorganisms have profound effects on the environment around them and have influenced biochemical and mineralogical processes throughout time. This course will explore the impact microorganisms have on geological processes. Students will prepare a NSF-style report and defend it.

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**BIO SCI 6353 Advanced Cancer Cell Biology** (LEC 3.0)

Graduate level biology course examining cellular processes that go awry during tumorigenesis. We will discuss cell cycle controls, signal transduction pathways, DNA repair, telomerase, apoptosis, cell migration and adhesion that are altered in cancer cells. In addition to lecture, will include a weekly section to examine primary cancer literature. Prerequisite: Bio Sci 2213.

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**BIO SCI 6363 Advanced Freshwater Ecology** (LEC 3.0)

The ecology of streams, lakes, and wetlands. The course will cover the physical and chemical characteristics of freshwater environments, the diversity of life in freshwaters, biogeochemical processes, and threats to freshwater systems. Research proposal and additional readings required for graduate credit. Prerequisite: Graduate student standing.

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**BIO SCI 6373 Advanced Stem Cell Biology** (LEC 3.0)

This course will cover the fast-moving field of stem cell biology. Topics include: development and organogenesis, regeneration and repair, stem cell types and sources, pluripotency and reprogramming, stem cells and cancer, therapeutics, and ethics. Research proposal and additional readings required for graduate credit.

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**BIO SCI 6383 Advanced Toxicology** (LEC 3.0)

We will discuss the toxicity and mechanisms of action of natural and man-made toxicants. The impact of toxicants on both human health and the environment will be considered. Students will be assigned to independent literature search and write a report. Prerequisites: Bio Sci 2213.

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**BIO SCI 6413 Molecular Cell Biology** (LEC 3.0)

Advanced study of the biology of eukaryotic cells, including biomembranes and membrane transport, subcellular organelles, cellular energetics, protein sorting, cytoskeletal elements, cell to cell signalling, regulation of the cell cycle, and tissue organization. Prerequisite: Bio Sci 2213 or equivalent.

**BIO SCI 6423 Astrobiology** (LEC 3.0)

The origins of life on early earth and the possibility of life on extraterrestrial bodies will be explored in this course through lectures and journal article discussions. In addition, the means to study extraterrestrial environments will be considered. Prerequisite: Graduate standing.

**BIO SCI 6433 Advanced Genomics** (LEC 3.0)

An overview of the field of genomics. Topics covered include genome sequencing and annotation, transcriptomics, proteomics, metabolomics, genomic variation, and human, and several animal, plant, and microbial genome projects. Students will complete an independent genomics project that incorporates concepts and bioinformatics tools learned. Prerequisites: Students may not receive credit for both Bio Sci 4433 and Bio Sci 6433.

**BIO SCI 6463 Bioremediation** (LEC 3.0)

During this course, the use of microorganisms and other living organisms for the remediation of contaminated environments will be explored along with the techniques necessary for monitoring their activities. Prerequisite: Graduate standing.

**BIO SCI 6513 Advanced Microbial Metabolism** (LEC 3.0)

A survey of the diverse metabolic properties of microorganisms. Course material will emphasize major metabolic pathways and how they relate to microbial diversity and microbial ecology. Prerequisite: Bio Sci 3313 or an equivalent course.

**BIO SCI 6523 Advanced Biomolecules** (LEC 3.0)

Demonstration of the principles of modern biochemistry as they relate to the structure and function of the major macromolecules of the cell. An emphasis will be placed on reading and interpreting scientific literature and scientific writing. Prerequisite: Bio Sci 2213 or Chem 4610 or an equivalent course.

**BIO SCI 6533 Advanced Neurobiology** (LEC 3.0)

A course in cellular neurobiology. Emphasis will be placed on the unique properties of neurons and other excitable cells. Topics include the structure and biophysical properties of neurons, synaptic transmission, neurochemistry, signal transduction, neuropharmacology and neurodevelopment. Students will give a 30 min class presentation on a relevant subject. Prerequisites: Students may not receive credit for both Bio Sci 4533 and Bio Sci 6533.

**BIO SCI 6563 Advanced Global Ecology** (LEC 3.0)

This class covers ecological topics at large scales, emphasizing global scales. Topics include global energy balance, biogeochemical cycles of water, carbon, nitrogen, and other biologically important elements, and global biodiversity. Students will focus on primary literature related to global ecology. Research proposal and additional readings required. Prerequisites: Students may not receive credit for both Bio Sci 4563 and Bio Sci 6563.

**BIO SCI 6666 Advanced Nanotechnology in Biomedicine** (LEC 3.0)

Applications of nanotechnology in life science is termed nanobiotechnology. This course describes recent development of nanotechnology in basic biological research as well as biomedical applications. In addition to attending regular lectures, graduate students will be assigned to an independent research project and present the information in the class. Prerequisites: Bio Sci 2213 and Bio Sci 2223 and graduate standing.

## Business Administration

The business and information technology department offers a unique master of business administration (MBA). The MBA is a professional degree that combines core business knowledge with specialization tracks that include the newest technology trends, all in an environment of team based project work, business plan development, live simulations, and employer networking. In addition to influential presentation skills and advanced problem solving competencies, MBAs develop advanced strategic thinking skills that are required of the leaders of today and tomorrow.

## Financial Assistance

Financial assistance is available to graduate students in the form of assistantships and fellowships. Research opportunities for advanced students exist. For application forms, contact the department

## Additional Information

Contact us at 573-341-7216, bit@mst.edu or visit <http://bit.mst.edu>.

## Admissions Requirements

In addition to the requirements set by the office of admissions and the office of graduate studies, specific requirements for admission to the MBA program are as follows:

- Successful completion of an undergraduate degree from a recognized college or university with a GPA (grade point average or international equivalent) of 3.0/4.0 or better.
- Submission of scores from the Graduate Record Exam (GRE) or the Graduate Management Admissions Test (GMAT).
- TOEFL or IELTS scores must be submitted if English is not the candidate's natural language.

\*\*\*Please note that meeting the above requirements does not guarantee admission into the MBA program, but, rather, is used by the admissions committee in the decision-making process\*\*\*

## Degree Requirements

In today's business environment, management requires the ability to leverage information across business functions and knowledge across internal and external boundaries. Students work in teams on comprehensive business cases, live simulations and real company assigned projects throughout the MBA program.

The Missouri S&T MBA requires a total of 36 graduate credit hours (5000-level and above) and is offered in two (2) parts: the MBA Core (21 credits) and electives (15 credits). The MBA core classes include BUS 6121, BUS 6622, BUS 6723, BUS 6224, BUS 6425, BUS 6426, and BUS 6827. Courses below the 5000-level will not count toward the MBA degree, even if they are taken to fulfill prerequisites. A maximum of 6 credit hours may

be taken outside the Business and Information Technology department, except where taking one of the approved Graduate Certificates listed below requires otherwise.

The business and information technology department offers a variety of graduate certificates. Each certificate program consists of four courses and is open to persons holding a bachelor's, master's or Ph.D degree in areas such as business, social sciences, technology, engineering, or related disciplines who have the required pre-requisites for the courses in the program. A student must maintain an average cumulative grade point of 3.0 or better on a 4.0 scale in the certificate courses in order to receive the graduate certificate.

Students may apply to be admitted only to a graduate certificate program. If admitted, the student will have non-degree graduate status but will earn graduate credit for the courses completed. If a student completes the four graduate certificate courses with a grade of B or better in each of the courses taken, the student may be admitted to the master of business administration or to the master of science in information science and technology if the student so chooses. A student must, however, follow the normal application process and meet other program prerequisites. The graduate certificate credits will count toward the student's MBA or M.S. degree.

The current list of approved graduate certificates includes:

- Business analytics and data science
- Business intelligence
- Business project management
- Cybersecurity and information assurance management
- Digital media and web design
- Digital supply chain management
- Electronic and social commerce
- Enterprise resource planning
- Entrepreneurship and technological innovation
- Finance
- Financial Technology
- Human-computer interaction and user experience
- Information system project management
- Management and leadership
- Mobil business and technology
- Military construction management (offered by engineering management program)
- Military geological engineering (offered by geological sciences and engineering programs)

Additional graduate certificates may be approved for the department.

Details about some of the graduate certificates are listed below; others are listed in the information science and technology section of the catalog.

## Business Project Management

This certificate aims to equip students with a set of tools that will allow them to achieve Project Management Institute (PMI) standards in the project management area to successfully manage resources and to analyze, evaluate and improve complex projects. Specifically, the ability to:

- Identify operations problems and implement solutions for improved strategic competitiveness
- Make sound decisions, plan, and control the key resources of an organization - money and people
- Critically analyze, evaluate, improve, or adapt existing technical and/or managerial systems
- Organize and manage complex projects

A student admitted to this graduate certificate must complete four courses:

BUS 6425	Supply Chain and Project Management
BUS 6723	Artificial Intelligence, Robotics, and Information Systems Management
ENG MGT 5320	Project Management
ENG MGT 6322	Case Studies in Project Management

## Entrepreneurship and Technological Innovation

Change and growth in Missouri and America require the training, nourishing, and flourishing of entrepreneurs. Many college students, however, do not yet recognize the entrepreneurial spirit in themselves. Recent entrepreneurship research indicates that many of the skills and much of the knowledge of successful entrepreneurs can be developed and taught in the classroom. The department of business and information technology has created this certificate to spark the entrepreneurial spirit in the students of Missouri S&T, and provide them with a solid foundation on which to build.

To that end, the program focuses on the following competencies:

- Recognizing opportunity
- Assessing opportunity
- Planning under uncertainty
- Fostering innovations
- Mastering creativity
- Building and managing networks
- Leveraging resources
- Mitigating and managing risk
- Focus and adaptability
- Design thinking
- Implementing new ideas

A student admitted to this graduate certificate must complete four courses:

BUS 5980	Business Models for Entrepreneurship and Innovation
MKT 5310	Digital Marketing and Promotions

Two courses from the following list:

BUS 5580	Strategic Management
BUS 6150	Advanced Customer Focus and Satisfaction
IS&T 5251	Technological Innovation Management and Leadership
IS&T 5886	Prototyping Human-Computer Interactions
IS&T 6335	Mobile Technology for Business
IS&T 6654	Advanced Web and Digital Media Development

## Finance

This certificate provides in-depth exposure to finance, including managerial and corporate finance, as well as investments and financial

statement analysis and modeling. Skills will be enhanced in financial theory, financial markets, and decision-making in investments, with career options as budget analysts/financial analysts, risk management specialists, capital advisors, and investment underwriters, among others.

A student admitted to this graduate certificate must complete four courses:

BUS 6827	Managerial Finance
Three courses from the following list:	
FINANCE 5160	Corporate Finance II
FINANCE 5260	Investments I
BUS 5230	Financial Statement Analysis
FINANCE 5310	Financial Technology and Analytics

## Financial Technology

This certificate deals with the aim of making financial systems more efficient. It exists at the intersection of information systems and finance. FinTech is a range of disruptive technological approaches within the money, market, marketplace, and financial infrastructure spheres. From cryptocurrencies and blockchain to enterprise software and asset management via robo-advisors, financial service functions are increasingly based on growing and innovative technology.

A student admitted to this certificate must complete four courses:

FINANCE 5310	Financial Technology and Analytics
IS&T 5420	Business Analytics and Data Science
One course from the following list:	
FINANCE 5160	Corporate Finance II
FINANCE 5260	Investments I
BUS 5230	Financial Statement Analysis
One course from the following list:	
IS&T 5520	Data Science and Machine Learning with Python
IS&T 6450	Information Visualization
BUS 6723	Artificial Intelligence, Robotics, and Information Systems Management
IS&T 6780	Adv Human and Organizational Factors in Cybersecurity
ERP 5210	Performance Dashboard, Scorecard and Data Visualization

## Management and Leadership

This certificate is designed to prepare students to be the leaders of the future, by enabling them to manage through the use of technology. Understanding technology is becoming ever more critical in business as a tool used by efficient and effective managers. These leaders not only understand the managerial process and how to inspire others, but also know how to harness technology to expedite the process. The certificate incorporates management theories, technological savvy, and leadership skills to create a student who is ready for the challenges of a fast paced managerial position.

A student admitted to this graduate certificate must complete four courses:

Required Core Course:

BUS 6121 Team-building and Leadership

Elective Courses (Choose Three):

BUS 5580: Strategic Management

IST 5251 Technological Innovation Mgmt and Leadership

IST 6261: Advanced Information Systems Project Management

IST/PHILOS 5168 – Law and Ethics in E-Commerce

BUS 6111 - Business Negotiations

MKT 6150 - Advanced Customer Focus and Satisfaction

BUS 5470 - Human Resource Management

EMGT 5320 – Project Management

BUS 6425 - Supply Chain and Project Management

BUS 6723 - Artificial Intelligence, Robotics, and Information Systems Management

**Carla Pauline Bates**, Assistant Teaching Professor  
PHD University of Missouri-Columbia  
Learning styles, learning technologies.

**Robert T Berry**, Adjunct Instructor  
PHD University of Kansas  
Project management, business negotiations, general management.

**Darryl Lee Brinkmann**, Adjunct Instructor  
MASTER Sangamon State University  
General management, human resource management.

**Langtao Chen**, Assistant Professor  
PHD Georgia State University  
Data analytics, human-computer interaction, social media, health informatics, machine learning, gameful design.

**Yu Hsien Chiu**, Associate Teaching Professor  
MASTER University of Wisconsin-Milwaukee  
Enterprise resource planning, management information systems, business intelligence.

**Cecil Chua**, Associate Professor  
PHD Georgia State University

**Craig C Claybaugh**, Associate Professor  
PHD University of Wisconsin-Milwaukee  
Enterprise resource planning, information technology vendor-client relationships, online trust, social networking.

**Cassandra Carlene Elrod**, Associate Professor  
PHD University of Missouri-Rolla  
Marketing in higher education, operations management, supply chain management, continuous improvement, project management, quality, and lean enterprise.

**Li-Li Eng**, Associate Professor  
PHD University of Michigan Ann Arbor  
Financial and managerial accounting, international accounting.

**Hanqing Fang**, Assistant Professor  
PHD Mississippi State University

**Barry B Flachsbar**, Professor Emeritus  
PHD Stanford University  
Large databases, manufacturing information systems, information systems project management, team building and leadership, machine learning and artificial intelligence.

**Nobuyuki Fukawa**, Associate Professor  
PHD Louisiana State University  
Consumer behavior, marketing research, marketing strategy.

**Richard H Hall**, Emeritus  
PHD Texas Christian University  
Human-computer interaction with a focus on learning technologies.

**Edward J Harvey**, Adjunct Instructor  
MBA University of Missouri-Columbia  
General management, human resource management.

**Michael Gene Hilgers**, Professor  
PHD Brown University  
Modeling and simulation, leaning technologies, and human-computer interaction.

**Bih-Ru Lea**, Associate Professor  
PHD Clemson University  
Enterprise resource planning, performance dashboards, accounting information systems, data visualization, business process integration, and supply chain management.

**Yu Liu**, Assistant Professor  
PHD University of Oregon  
Empirical corporate finance, investment, OTC market, public finance, and political economics.

**Fiona Fui-Hoon Nah**, Professor  
PHD University of British Columbia  
Management information systems, E-commerce, mobile commerce, human-computer interaction.

**Keng Leng Siau**, Professor  
PHD University of British Columbia  
Artificial intelligence/machine learning, business intelligence/analytics, design science, mobile, and ubiquitous business.

**Sarah Margaret Stanley**, Associate Professor  
PHD Saint Louis University  
Brand relationships, advertising effectiveness, social marketing and its effects on consumer brand choice.

**Wen-Bin Yu**, Associate Professor  
PHD University of Louisville  
Business intelligence, text mining, data mining, demand forecasting, simulation, and agent bases systems.

**Hongxian Zhang**, Assistant Professor  
PHD University of Texas at San Antonio  
Corporate finance, investments, public pension funds.

**BUS 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department.  
Prerequisite: Admission to the MBA program.

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**BUS 5001 Special Topics** (LEC 0.0-6.0)  
This is designed to give the department an opportunity to test a new course. Variable title.

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**BUS 5040 Oral Examination** (IND 0.0)  
After completion of all other requirements, oral examinations for on-campus M.B.A./Ph.D. students may be processed during intersession. Off-campus M.B.A. students must be enrolled in oral examination and must have paid an oral examination fee at the time defense/oral examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**BUS 5080 Practicum** (IND 0.0-6.0)  
This course is similar to the Bus 5085 Internship course. The difference is that this course is intended for students who are already employed by an organization for whom they wish to continue working. Prerequisite: Bus Core.

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**BUS 5085 Internship** (IND 0.0-6.0)  
Students apply critical thinking skills and discipline specific knowledge in a work setting based on a project designed by the advisor and employer. Activities will vary depending on the student's background and the setting. Requires major report and formal presentation to sponsoring organization. Prerequisite: Graduate standing.

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**BUS 5099 Research** (IND 0.0-9.0)  
Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Permission of the instructor.

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**BUS 5105 Graduate Management and Business Law Essentials** (LEC 1.5)  
This course is an introduction to the essentials of management and business law for running a business. It's designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

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**BUS 5115 Introduction to Individual and Group Dynamics in Business** (LEC 3.0)  
This course will cover contemporary theories of business leadership styles and group dynamics. Leadership theories, group dysfunction/function, positive group interactions, change impacts, the importance of business ethics as well as the role of gender and culture on the group will be examined.

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**BUS 5205 Graduate Accounting Essentials** (LEC 1.5)  
This course is an introduction to the essentials of financial and managerial accounting for running a business. It's designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

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**BUS 5230 Financial Statement Analysis** (LEC 3.0)

Analysis and interpretation of financial statements for profitability analysis, credit analysis, and other business analyses that rely on financial data. Introduces emerging roles of accounting analytics. Illustrates data analytics concepts and techniques to detect earning management, predict fraud, and to provide insights into other business strategies. Prerequisite: Finance 2150 or equivalent basic corporate finance knowledge.

**BUS 5305 Graduate Operations Management Essentials** (LEC 1.5)

This course is an introduction to the essentials of operations management for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

**BUS 5360 Business Operations** (LEC 3.0)

This course examines the concepts, processes, and institutions that are fundamental to an understanding of business operations within organizations. Emphasis is on the management and organization of manufacturing and service operations and the application of quantitative methods to the solution of strategic, tactical and operational problems. Prerequisites: BUS 1210 or ENG MGT 2211; at least Junior standing; and one of the following: STAT 1111, STAT 1115, STAT 1116, STAT 3111, STAT 3113, STAT 3115, or STAT 3117.

**BUS 5470 Human Resource Management** (LEC 3.0)

The course examines employee selection, performance appraisal, training and development, compensation, legal issues, and labor relations. Prerequisite: Bus 1110.

**BUS 5580 Strategic Management** (LEC 3.0)

Study of the formulation and implementation of corporate, business and functional strategies designed to achieve organizational objectives. Case studies and research reports may be used extensively. Prerequisites: MKT 3110 or Eng Mgt 3510; Finance 2150 or Eng Mgt 3200; Senior standing.

**BUS 5705 Graduate Management Information Systems Essentials** (LEC 1.5)

This course is an introduction to the essentials of management information systems for running a business. It is designed for students planning to enter the MBA program. Credit in this course cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

**BUS 5730 Machine Learning and Artificial Intelligence for Business** (LEC 3.0)

Explores various approaches to machine learning and artificial intelligence, along with their numerous applications in business. Describes some of the many technological approaches to business problems that are considered part of machine learning and artificial intelligence, such as neural networks and deep learning. Prerequisites: IS&T 1750; or Graduate Standing, understanding of management information systems.

**BUS 5805 Graduate Mathematics and Statistics Essentials** (LEC 1.5)

This course is an introduction to the essentials of mathematics and statistics for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

**BUS 5896 Project Research** (IND 0.0-9.0)

The research project will involve students applying research techniques and discipline specific knowledge working on a project designed by the advisor, often working with a business organization. Requires major report and formal presentation to sponsoring organization. Prerequisite: Permission of the instructor.

**BUS 5910 Privacy and Information Security Law** (LEC 3.0)

Explores issues concerning the use, disclosure, and protection of information (personal, organizational, health, and financial) from a legal perspective. A focus on understanding, planning, protecting, and responding to data breaches and other information risk and threats. Case studies based on litigation are reviewed and analyzed. Assumes MIS familiarity.

**BUS 5980 Business Models for Entrepreneurship and Innovation** (LEC 3.0)

This course uses problem based learning to expand student insight into the nature, development, and application of business models. It increases the practical skills and knowledge required to generate original models of value creation for both entrepreneurial start-ups and corporate innovation. Prerequisite: Senior or graduate standing.

**BUS 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Prerequisite: Admission to the MBA program.

**BUS 6001 Special Topics** (IND 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

**BUS 6099 Research** (IND 0.0-9.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Permission of the instructor.

**BUS 6111 Advanced Business Negotiations** (LEC 3.0)

The purpose of this course is to understand the practices and processes of negotiation for negotiating successfully in a variety of settings. The course is designed to be relevant to the broad spectrum of negotiation problems faced by managers, consultants, etc. A negotiation project is also required. Prerequisite: Graduate status.

**BUS 6121 Teambuilding and Leadership** (LEC 3.0)

This class will teach students how to work well in teams and lead teams and organizations. Management, networking, presentation skills, and sustainable business practices will be covered. MBA core. Prerequisite: Graduate standing.

**BUS 6150 Advanced Customer Focus and Satisfaction** (LEC 3.0)

Major emphasis is given to the concept of customer focus, with coverage of techniques for obtaining customer needs, measuring customer satisfaction, developing products and services to satisfy customers, and maximizing the benefits of customer feedback. Individual focused research is included. Prerequisites: MKT 3110 or MKT 3105 or ENG MGT 3510. (Co-listed MKT 6150).

**BUS 6224 Managerial Accounting and Control** (LEC 3.0)

This course covers managerial accounting and its critical role in decision making, monitoring, and controlling business processes. MBA core. Prerequisite: Graduate standing.

**BUS 6425 Supply Chain and Project Management** (LEC 3.0)

This course covers supply chain management and its critical role in developing and maintaining effective and efficient processes in the organization, including operations and project management processes and principles. MBA core. Prerequisite: Graduate standing.

**BUS 6426 Integration of Business Areas** (LEC 3.0)

Students will acquire knowledge to integrate the business functions to maximize performance efficiency and effectiveness. It will be covered through case studies and readings. MBA core. Prerequisite: Graduate standing.

**BUS 6622 International Marketing** (LEC 3.0)

This course focuses on the challenges faced by business managers as they deal with a competitive global market. The course will examine various topics related to international marketing such as cultural differences, economic differences, differences in product and technical standards, global advertising, and international pricing and segmentation. MBA core. Prerequisite: Graduate standing.

**BUS 6675 Advanced International Business** (LEC 3.0)

Business concepts, analytical processes and philosophical bases for international business operations. Emphasis is on environmental dynamics, multinational business organizations, cultural and economic constraints, unique international business practices and international operations, strategy and policy. Research project required. Prerequisites: MKT 3110 or MKT 5105 or Eng Mgt 3510.

**BUS 6723 Artificial Intelligence, Robotics, and Information Systems Management** (LEC 3.0)

The course, designed for business executives, covers management of information to revitalize business processes, improve business decision-making, embrace emerging and disruptive technologies, and gain competitive advantages. The course also covers implications of AI, automation, machine learning, and robotics on business and society. MBA core. Prerequisite: Graduate standing.

**BUS 6827 Managerial Finance** (LEC 3.0)

This course covers the use of financial tools to manage the organization. The main focus is the strategic decision-making process of modern managers responsible for major financial decisions. Topics include financial policy, capital investment analysis, dividend policy, capital structure, and other contemporary corporate finance issues. MBA core. Prerequisite: Graduate standing.

**BUS 6887 Research Methods in Business and IS&T** (LEC 3.0)

This course covers quantitative and qualitative research methods for exploring the interaction between people and information technologies. The course covers techniques and tools for carrying out literature reviews, forming research goals, designing research, conducting data analyses; and preparing manuscripts and live presentations. (Co-listed with IS&T 6887).

## Ceramic Engineering

The ceramic engineering program in the department of materials science and engineering offers comprehensive graduate education in a number of areas including structural ceramics, electronic materials, high temperature materials, and glass. Further information on these opportunities and facilities available to carry out research in ceramic engineering may be found under materials science and engineering.

## Degree Requirements

M.S. and Ph.D. degrees are offered in ceramic engineering. The total number of hours required for the M.S. in ceramic engineering is 30. A minimum of 6 hours of 6000-level lectures and a minimum of 11 hours of graduate research on the Missouri S&T campus are required. A maximum of 6 hours of 4000-level lecture credit may be accepted.

The minimum number of hours (beyond the bachelor's degree) required for the Ph.D. in ceramic engineering is 72. At least 12 hours of course work outside of ceramic engineering is recommended, a minimum of 24 hours will be dissertation research, and a minimum of 24 hours must be course work. Students will also be required to take and pass qualifying and comprehensive exams in accordance with Missouri S&T rules.

**Richard K Brow**, Curators Distinguished Professor  
PHD Pennsylvania State University  
Curators' Professor of Ceramic Engineering, and Senior Investigator,  
Graduate Center for Materials Research.

**Anthony Convertine**, Assistant Professor  
PHD University of Southern Mississippi

**Fatih Dogan**, Professor  
PHD Technical University of Berlin

**Arezoo Emdadi**, Assistant Professor  
PHD Missouri University of Science and Technology

**William G Fahrenholtz**, Curators Distinguished Professor  
PHD University of New Mexico  
Director, Graduate Center for Materials Research.

**Gregory E Hilmas**, Curators Distinguished Professor and Department Chair  
PHD University of Michigan-Ann Arbor

**Wayne Huebner**, Professor  
PHD University of Missouri-Rolla

**Aditya Kumar**, Assistant Professor  
PHD Ecole Polytechnique Federale de Lausanne (EPFL)

**David Lipke**, Assistant Professor  
PHD Georgia Institute of Technology

**Jeffrey D Smith**, Professor  
PHD University of Missouri-Rolla

**Jeremy Lee Watts**, Associate Research Professor  
PHD Missouri S&T

**Kelley Wilkerson**, Assistant Teaching Professor  
PHD Missouri University of Science and Technology

**CER ENG 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CER ENG 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**CER ENG 5002 Cooperative Training** (IND 1.0-3.0)  
On-the-job experience gained through cooperative education with industry, with credit arranged through departmental cooperative advisor. Grade received depends on quality of reports submitted at work supervisor's evaluation.

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**CER ENG 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CER ENG 5099 Research** (IND 0.0-15)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CER ENG 5115 X-Ray Diffraction Analysis** (LEC 2.0 and LAB 1.0)  
Theory and practical aspects of x-ray diffraction analysis are covered including diffraction theory, qualitative and quantitative analysis techniques, electronic databases, and operation of modern powder diffractometers. Students cannot receive credit for both Cer Eng 3417 and Cer Eng 5115. Prerequisite: Preceded or accompanied by Cer Eng 3410.

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**CER ENG 5220 Advanced Mechanical Properties of Ceramics** (LEC 3.0 and LAB 1.0)  
An advanced course to treat the theory and testing practice related to design based on the mechanical properties of ceramics. The course also includes a laboratory consisting of experiments for the characterization of the mechanical properties of ceramics. Prerequisites: Graduate standing.

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**CER ENG 5230 Glass Science And Engineering** (LEC 3.0)  
The development, manufacturing methods, applications, and properties of flat, fiber, container, chemical, and special purpose glasses. Composition/property relationships for glasses and nucleation-crystallization processes for glass-ceramics are also covered. Prerequisite: "C" or better grade in Cer Eng 2120.

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**CER ENG 5250 Refractories** (LEC 3.0)  
The manufacture, properties, uses, performance, and testing of basic, neutral and acid refractories. Prerequisite: Cer Eng 3230.

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**CER ENG 5260 Dielectric And Electrical Properties Of Oxides** (LEC 3.0)  
The processes occurring in inorganic materials under the influence of an electric field are considered from basic principles. Emphasis is placed on application to real systems. Prerequisite: "C" or better grade in Cer Eng 4210.

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**CER ENG 5310 Advanced Ceramic Processing** (LEC 3.0)  
Materials, processing and design of microelectronic ceramics are covered. Introduction to devices, triaxial ceramics, high aluminas, tape fabrication, metallizations, thick film processing and glass-to-metal seals. Prerequisites: Cer Eng 3210 & 3325.

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**CER ENG 5810 Principles Of Engineering Materials** (LEC 3.0)  
Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Met Eng 5810).

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**CER ENG 6000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CER ENG 6001 Special Topics** (IND 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**CER ENG 6050 Continuous Registration** (IND 1.0)  
Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CER ENG 6085 Internship** (IND 0.0-15)  
Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**CER ENG 6099 Research** (IND 0.0-15)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CER ENG 6220 Optical Properties Of Materials** (LEC 3.0)

The objective of this course is to give the student a fundamental understanding of the structure-optical property relationships exhibited by isotropic and anisotropic materials. Topics will include the wave/particle nature of light, how light interacts with materials, color, and applications such as lasers, fiber optic communication systems, electro-optics, and integrated optics. Prerequisites: Physics 2135 or 2111 and Math 2222.

**CER ENG 6230 Composite Materials** (LEC 3.0)

The objective of this course is to provide students an advanced understanding of process-structure-property relationships in composites. Topics will include composite architecture, constituents, interfaces, fabrication techniques, analytical and numerical micromechanics and macromechanics, design criteria, and contemporary issues in composite materials. Prerequisite: Graduate Standing.

**CER ENG 6240 Advanced Topics On The Vitreous State** (LEC 3.0)

Modern aspects of the structure and dynamics of inorganic vitreous materials will be reviewed and applied towards understanding the macroscopic properties of glasses. Prerequisite: Graduate standing.

**CER ENG 6260 Advanced Electrical Properties of Ceramics** (LEC 3.0 and LAB 1.0)

The application of ceramic chemistry and physics to the development and evaluation of electronic, dielectric, magnetic, and optical properties. Emphasis is placed on the relationships between properties and crystal structure, defects, grain boundary nature, and microstructure. Prerequisite: Grade of "C" or better in Physics 2305.

**CER ENG 6310 Sintering And Microstructure Development** (LEC 3.0)

Theory and practice of densification, microstructure evolution, effect of processing and material factors, grain boundary migration, grain growth. Prerequisite: Graduate standing.

**CER ENG 6410 Advanced Integrated Computational Materials Engineering** (LAB 1.0 and LEC 2.0)

Students will learn of different computational tools for studying materials at different length scales. The bridging between different modeling scales will be discussed. This course has a computational laboratory to build models and run simulations. Students will complete a final project by integrating two length-scale models. Prerequisite: A grade of "B" or better grade in Math 3304.

## Chemical & Biochemical Engineering

The department of chemical and biochemical engineering occupies the 68,000 square foot state-of-the-art Bertelsmeyer Hall. The department has excellent research laboratories and computer facilities equipped to handle cutting edge research and all chemical engineering related computational, modeling, and simulation requirements.

Special areas for instruction and research are maintained and include excellent and modern facilities for computer simulation and modeling; control and optimization; bio-conversion; multiphase reactors engineering, catalysis; reaction mechanisms and kinetics; fluid mechanics and mixing; thermodynamics; polymers and polymeric materials; freeze drying; adsorption/desorption processes; membrane technology; interfacial phenomena; enhancement oil recovery; transport phenomena; chromatography; characterization of biomolecules;

synthesis of nano-particles; nano-film coating; drug delivery; supercritical fluid technology, energy, bioenergy, hybrid energy and environmental applications including CO<sub>2</sub> capture.

The department of chemical and biochemical engineering offers M.S. and Ph.D. degrees in chemical engineering.

A baccalaureate degree in chemical engineering with a minimum undergraduate grade point average of 3.0/4.0 or equivalent is required for admission to the graduate program.

The department specializes in research in the areas of fluid mechanics, supercritical fluid technology, reaction engineering, biochemical engineering, mass and heat transfer in porous media, transport and interfacial phenomena, computer-aided design, particle characterization, catalysis, statistical mechanics and nanotechnology.

All students, except for those in their first semester and in their last semester for PhD candidates, need to register for 1 credit hour of CHEM ENG 6015 Lecture Series. Lecture Series can be used for a total of 3 hours towards the students 6000 level requirement.

The master of science thesis program consists of a minimum of 30 semester hours, including 18-24 hours of coursework, in which CHEM ENG 5100, CHEM ENG 5110, CHEM ENG 5150 and CHEM ENG 5220 are required. In addition, a thesis from research that is equivalent to 6-12 credit hours in the major area must be prepared and defended.

A master of science non-thesis program consists of 30 semester hours of coursework, including CHEM ENG 5100, CHEM ENG 5150, CHEM ENG 5110, CHEM ENG 5220 and a minimum of 24 hours of coursework within the department. The program of study must include nine credit hours of 6000 level courses.

A candidate for the Ph.D. degree normally follows a program of 72 semester hours beyond the BS degree or 42 semester hours beyond the MS degree. Research for M.S. and Ph.D. may be coordinated, or a Ph.D. may be pursued without an M.S. degree. The Ph.D. coursework must satisfy the departmental core course requirements for the M.S. degree with an additional 6 credit hours of 6000-level coursework for a minimum of 12, 6000-level credit hours. In addition to these course requirements, a candidate must prepare and defend a dissertation based on analytical and/or experimental research.

All Ph.D. students must pass the qualifying exam which consists of written and oral assignments specified by the department.

At least three members of the advisory committee have to be ChE faculty. The comprehensive examination, consisting of a written and oral presentation of a research proposal, should be taken in the semester following the completion of their course work and no later than six months prior to the final examination. The final examination, consisting of the dissertation defense, is conducted according to the rules of the graduate faculty, College of Engineering and Computing, and the department.

**Muthanna Hikmat Al Dahhan**, Professor

DSc Washington University

Multiphase reaction and reactor engineering flow systems; transport-kinetic integration; advanced measurement and computational techniques; applications to green technology and sustainable development in energy, products, and environment.

**Baojun Bai**, Professor

PHD New Mexico Institute of Mining  
Enhanced oil recovery target, conformance control, surfactants, biosurfactants, carbon sequestration.

**Dipak Barua**, Assistant Professor

PHD North Carolina State University  
Quantitative systems biology, multiscale modeling and simulation, immunoreceptor and cancer cell signal transduction.

**Sutapa Barua**, Assistant Professor

PHD Arizona State University  
Nanoparticles for drug delivery, biosensor for real-time monitoring of contaminants in pharmaceutical solutions; bioseparation of toxins with biocompatible nanoparticles, pharmaceutical purification and polymer microparticle-based cell culture in liquid suspension for cell therapy.

**Daniel Forciniti**, Professor

PHD North Carolina State University  
Applications of molecular theories to problems in biochemical engineering and science. Bioseparation. Protein characterization and computer simulations of biological systems.

**Chang-Soo Kim**, Professor

PHD Kyungpook National University  
Functional integration and structural integration of advanced microsystems, biosensors.

**Xinhua Liang**, Associate Professor

PHD University of Colorado-Boulder  
Surface science and catalysis, nano-structured films and devices, energy and environmental applications.

**Douglas K Ludlow**, Professor

PHD Arizona State University  
Surface characterization, catalysts, adsorption.

**Angela Lueking**, Professor

DE University of Michigan

**Christi Luks**, Teaching Professor

PHD University of Tulsa  
Engineering education pedagogy, sustainable engineering.

**Parthasakha Neogi**, Professor

PHD Carnegie Mellon University  
Interfacial and transport phenomena.

**Monday Okoronkwo**, Assistant Professor

PHD University of Aberdeen  
Chemistry of materials for sustainable infrastructure, energy, and environment.

**Fateme Rezaei**, Assistant Professor

PHD Monash University - Melbourne, Australia  
Adsorption, energy efficient separation processes, process design, modeling and optimization; PSA/TSA; and hybrid materials and process for separation and reaction.

**Ali Rowanghi**, Assistant Teaching Professor

PHD University Putra - Malaysia  
Sustainable energy; catalysis; separations.

**Peter J Ryan**, Associate Teaching Professor

PHD University of Massachusetts-Amherst  
Process and control engineering, process analysis, design and optimization, six-sigma optimization, process simulation.

**Joseph D Smith**, Professor and Laufer Endowed Chair in Energy

PHD Brigham Young University  
Wayne and Gayle Laufer Endowed Energy Chair. Hybrid energy generation, renewable energy, gas flare performance, process modeling and control, computational fluid mechanics.

**Jee-Ching Wang**, Associate Professor

PHD Pennsylvania State University  
Molecular modeling and simulation, nanofluid and nanoparticle technology, interfacial phenomena and dynamics, transport in porous media, parallel computing and new simulation techniques.

**David J Westenberg**, Associate Professor

PHD University of California-Los Angeles  
Molecular microbiology, microbial diversity, microbial physiology.

**CHEM ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required. Prerequisite: Consent of Instructor Required.

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**CHEM ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CHEM ENG 5010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**CHEM ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CHEM ENG 5100 Intermediate Transport Phenomena** (LEC 3.0)

The similarities of flow of momentum, heat and mass transfer and the applications of these underlying principles are stressed. Course is primarily for seniors and beginning graduate students. Prerequisite: Chem Eng 3101 or graduate standing.

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**CHEM ENG 5110 Intermediate Chemical Reactor Design** (LEC 3.0)

A study of homogeneous and heterogeneous catalyzed and noncatalyzed reaction kinetics for flow and batch chemical reactors. Application to reactor design is stressed. Prerequisite: Chem Eng 3150 or graduate standing.

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**CHEM ENG 5120 Interfacial Phenomena In Chemical Engineering** (LEC 3.0)

The course deals with the effects of surfaces on transport phenomena and on the role of surface active agents. Topics include fundamentals of thermodynamics, momentum, heat and mass transfer at interfaces and of surfactants. Some applications are included. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5130 Risk Assessment and Reduction** (LEC 3.0)

Safe, secure manufacturing facilities protect the health of employees and the public, preserve the environment, and increase profitability. Methods for systematically identifying hazards and estimating risk improve the safety performance and security of manufacturing facilities. Prerequisite: Senior or Graduate Standing. (Co-listed with Eng Mgt 4312).

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**CHEM ENG 5150 Intermediate Process Computing** (LAB 1.0 and LEC 2.0)

Analysis of chemical processes from model development to solution. Emphasis on numerical computational techniques and tools appropriate for ordinary and partial differential equation solution. Prerequisite: Graduate standing.

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**CHEM ENG 5161 Intermediate Molecular Engineering** (LEC 3.0)

Molecular aspects of chemical thermodynamics, transport processes, reaction dynamics, and statistical and quantum mechanics, and their treatments in molecular-based modeling and simulation approaches. Prerequisites: Chem Eng 3120 or graduate standing.

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**CHEM ENG 5170 Physical Property Estimation** (LEC 3.0)

Study of techniques for estimating and correlating thermodynamic and transport properties of gases and liquids. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5190 Plantwide Process Control** (LEC 3.0)

Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Elec Eng 5350).

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**CHEM ENG 5200 Biomaterials I** (LEC 3.0)

This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisite: Senior undergraduate standing. (Co-listed with Bio Sci 5210, MS&E 5310).

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**CHEM ENG 5210 Intermediate Biochemical Reactors** (LEC 3.0)

Application of chemical engineering principles to biochemical reactors. Emphasis on cells as chemical reactors, enzyme catalysis and production of monoclonal antibodies. Projects on special topics and presentations related to the course materials will be included. Prerequisite: Preceded or accompanied by Chem Eng 3150 or graduate standing.

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**CHEM ENG 5220 Intermediate Engineering Thermodynamics** (LEC 3.0)

Review thermodynamic principles for pure fluids and mixtures. Emphasis on applications for the chemical industry and use of fundamental relations and equations of state. Prerequisite: Senior or graduate standing.

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**CHEM ENG 5250 Isolation and Purification of Biologicals** (LEC 3.0)

Isolation and purification of biologicals with emphasis on biopharmaceuticals. Principles and applications of chromatography, lyophilization, and product formulation. Use of ultrafiltration and diafiltration in the processing of protein products. Disposable technology. Prerequisites: Chem Eng 3131 and Chem Eng 3141.

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**CHEM ENG 5300 Principles Of Engineering Materials** (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Physics 4523, Met Eng 5810, Cer Eng 5810).

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**CHEM ENG 5305 Hazardous Materials Management** (LAB 1.0)

Major themes: hazard identification and characterization; safety, health and environmental management; and the protection of safety, health and environment. Students will have an understanding of work place and environmental hazards in order to be able to facilitate their management and control. The course will include an intensive 30 hour hands-on workshop Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5310 Structure and Properties of Polymers** (LEC 3.0)

A study of the parameters affecting structure and properties of polymers. Syntheses, mechanisms, and kinetic factors are emphasized from the standpoint of structural properties. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5315 Corrosion and Its Prevention** (LEC 3.0)

A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 2110 or Cer Eng 3230. (Co-listed with Met Eng 5310).

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**CHEM ENG 5320 Introduction to Nanomaterials** (LEC 3.0)

Introduction to the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Prerequisite: Chem Eng 2300, or Met Eng 1210 or Chem 1320.

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**CHEM ENG 5330 Alternative Fuels** (LEC 3.0)

Global energy outlook and available resources are discussed. Alternative energy options and their technologies are covered. Associated environmental concerns and technology are assessed. Special emphases are placed on renewable energies, transportation fuels, energy efficiencies, and clean technologies. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5340 Principles of Environmental Monitoring** (LEC 3.0)

This course introduces the fundamentals of particle technology, including particle characterization, transport, sampling, and processing. In addition, students will learn about the basic design of some industrial particulate systems and environmental and safety issues related to particulate handling. Prerequisites: Chem Eng 3101 or graduate standing.

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**CHEM ENG 5350 Environmental Chemodynamics** (LEC 3.0)

Interphase transport of chemicals and energy in the environment. Application of the process oriented aspects of chemical engineering and science to situations found in the environment. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CHEM ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CHEM ENG 6010 Graduate Seminar** (RSD 1.0-3.0)

Discussion of current topics. One of these topics will be expanded to write an in depth report. Prerequisites: Graduate standing.

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**CHEM ENG 6015 Lecture Series** (LEC 1.0)

Attendance of lecture series and submission of in-depth report on one of the covered topics is required for a grade. The course can be taken multiple times for a grade, with the same requirement each time, and up to three times to be counted for 6000 level course requirement. Prerequisites: Graduate standing.

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**CHEM ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus Ph.D. students may be processed during intersession. Off-campus Ph.D. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CHEM ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CHEM ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**CHEM ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CHEM ENG 6100 Advanced Chemical Engineering Thermodynamics** (LEC 3.0)

Extension of thermodynamic principles as applied to nonideal systems. Use of existing thermodynamic data and correlations with emphasis on applications of chemical engineering problems in energy, mass and momentum transfer.

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**CHEM ENG 6110 Advanced Transport Phenomena** (LEC 3.0)

Course is concerned with all aspects of transport phenomena. Complete expressions for heat, mass and momentum transfer in all three coordinate systems are applied under both laminar and turbulent conditions. Prerequisite: Chem Eng 5100.

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**CHEM ENG 6120 Applied Mathematics In Chemical Engineering** (LEC 2.0 and LAB 1.0)

An introduction to numerical methods for ordinary and partial differential equations arising in chemical engineering, bioengineering, and environmental engineering applications. Topics include finite difference and finite element methods; other numerical and analytical methods if time permits.

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**CHEM ENG 6140 Applied Optimization In Chemical Engineering** (LEC 3.0)

An introduction to modern optimization techniques having applications in engineering economics, data analysis, process design and dynamics; methods such as Fibonacci, Partan, steep ascent, geometric, mathematical and dynamic programming.

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**CHEM ENG 6150 Molecular Modeling and Simulation** (LEC 3.0)

Study of molecular-based modeling and simulation methodologies and their connections with each other and to multiscale modeling and other engineering approaches. Molecular Dynamics, Monte Carlo, Brownian Dynamics, statistical mechanics, and application cases in engineering and science are included. Prerequisite: Chem Eng 6100.

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**CHEM ENG 6180 Advanced Applications of Computational Fluid Dynamics** (LEC 3.0)

Advanced applications of CFD analyses is presented to investigate mass, momentum and heat transport in complex geometries with general initial and boundary conditions. Students will gain practical experience using commercial CFD codes and learn and apply a general algorithm for solving challenging industrial problems using tutorials. Prerequisites: Chem Eng 4150 and Chem Eng 5100.

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**CHEM ENG 6241 Intermediate Chemical Process Safety** (LEC 3.0)

The identification and quantification of risks involved in the processing of hazardous and/or toxic materials are studied. Methods to design safety systems or alter the chemical process to reduce or eliminate the risks are covered. Prerequisite: Graduate Standing.

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**CHEM ENG 6300 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required.

Prerequisite: Graduate Standing. (Co-listed with BIO SCI 6210, MS&E 6310).

**CHEM ENG 6310 Nanomaterials** (LEC 3.0)

Introduction of the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials.

Example nanomaterials include nanoparticles, nanotubes, and nanowires. Students will need to complete a project related to nanomaterials.

Prerequisite: Graduate Standing. (Co-listed with MS&E 6230).

**CHEM ENG 6330 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6611 and Civ Eng 6611).

## Chemistry

Our chemistry department is doing some of the most impactful research at the university and around the world. The department's 21 regular research faculty comprise one of the highest external research grant-generating departments at S&T. Our emphasis on excellence in research and creativity has moved our programs to the forefront of science. The department supports a broad range of research performed by internationally recognized faculty competing at the leading edge of technological research.

The department provides programs in analytical, inorganic, organic, physical, and biochemistry, as well as in more specialized areas including polymer and coatings, electrochemistry, bioanalytical chemistry, cancer biology, colloids, corrosion, environmental chemistry, kinetics, organometallic chemistry, reaction mechanisms, atmospheric sciences, solid state chemistry, chemical instrumentation design and development, spectroscopy and theoretical chemistry. A number of our faculty are involved in efforts which have been organized into several centers or institutes including the Missouri S&T Coatings Institute, the Materials Research Center, the Cloud and Aerosol Sciences Laboratory and the Center for Single Nanoparticle, Single Cell, and Single Molecule Monitoring. Financial support is available from research grants for advanced students.

The department of chemistry, along with the department of biological sciences, is housed in Schrenk Hall complete with modern research, teaching and computer laboratories. The department has a number of support personnel to provide technical assistance with laboratory instrumentation, computers, laboratory hardware, and glassware. State-of-the-art research instrumentation in the department of chemistry includes a Nicolet Nexus 470 FT-IR FTIR, Varian INOVA 400 MHz FT/NMR spectrometer with multinuclear liquid, diffusion, and variable-temperature capabilities, Bruker 200 MHz FT/NMR with multinuclear liquid and toroidal cavity capabilities, Beckman DU 640B and Carey 50 UV-Visible spectrophotometers, Hewlett Packard 5989A Mass Spectrometer (GC/

MS & DIP/MS inputs), Hitachi LaChrome Elite D-2000 HPLC with Diode Array & Refractive Index detectors, PerkinElmer 2380 Atomic Absorption spectrometer, Bruker-AXS D8 Single-crystal X-ray Diffractometer, Beckman PACE/MDQ capillary-electrophoresis, Shimadzu HPLC/GPC, EG&G potentiostat/galvanostats, TA Instruments Q2000 Differential Scanning Calorimeter, TA Instruments Q50 Thermogravimetric Analyzer, NexION 300 ICP-MS, and AB SCIEX 4000 QTRAP mass spectrometer, Tecna F20 TEM, S-570 SEM, PerkinElmer 2400 Elemental Analysis (C-H-N), PerkinElmer LS 30 Fluorescence spectrophotometer, Hewlett Packard 5890 series II Gas Chromatographs, Electrothermal Engineering Ltd. M-2341 Melting Point apparatus, Sartorius ME-5 series Ultra Micro Balance, Dymax Model 5000 UV Curing Oven, CEM MDS-2000 Microwave Reactor Oven, Nicolet Magna-IR 750, Bruker-AXS D8 Single-crystal X-ray Diffractometer, Hitachi M-8000 mass spectrometer, EG&G low-temperature Mössbauer spectrometer, Applied Color Systems 1800 color-matching/formulating computing spectrophotometer, PerkinElmer, Par 273, Rame-Hart 250-F1 Goniometer/Tensiometer, Full-Spectrum Laser MLE-40 Laser Cutter, Netzsch LFA447 Flash Diffusivity Analyzer, TA Instruments AR2000 Rheometer with Small-Angle Light Scattering attachment, TA Instruments Q800 Dynamic Mechanical Analyzer, and Applied Separations Helix Super-Critical Fluid Processor. The department houses an extensive collection of additional mass spectrometers, a wide variety of additional chromatographs (GC, LC, IC), infrared spectrometers, dispersive optical spectrometers (UV/VIS, IR, AA), fluorescence/luminescence spectrophotometers, centrifugal partition chromatographs, refrigerated-ultra centrifuges, calorimeters, salt-spray chambers, and radiation counters, as well as access to the campus centralized computing facility which includes numerically-intensive computing support. Neutron diffraction is on hand at the High Flux Reactor of the Missouri S&T. This also supports nuclear chemistry. Facilities for studying very fast combustions and explosions, as well as a variety of new and innovative techniques for characterizing high-energy materials, are provided in the Rock Mechanics and Explosives Research Center.

**Amitava Choudhury**, Associate Professor

PHD Indian Institute of Science, Bangalore

Solid state chemistry; Synthesis of polyanion-based materials, complex chalcogenides, porous materials (MOFs, organically templated solids, and zeolites); X-ray crystallography including single-crystal and powder X-ray diffraction (laboratory and synchrotron); Solid state electrochemistry (lithium- and sodium-ion batteries, solid electrolytes); Magnetic, electronic and thermoelectric properties.

**Richard Dawes**, Professor

PHD University of Manitoba, Canada

Spectroscopy and dynamics of small molecules primarily of interest to combustion and atmospheric chemistry.

**Nuran Ercal**, Professor

PHD Hacettepe University, Turkey

Vitek Chair of Biochemistry. Effects of N-acetylcysteineamide (NACA) in various oxidative stress related conditions, including metal toxicity, radiation, medicinal drug-induced toxicity, and degenerative eye disorders; Developing NACA eye drops as an alternative to surgery for oxidative stress-induced eye disorders; Developing HPLC techniques for thiol-containing compounds in biological samples.



**Rainer Glaser**, Professor and Chair

PHD University of California, Berkeley

CO<sub>2</sub> capture from air: Rubisco-inspired oligopeptide-based reversible CO<sub>2</sub> capture systems; Oscillating chemical reactions: Video-based kinetic analysis and complete simulation of complex reaction systems; Organic crystalline ferroelectric materials for nonlinear optics; Ethical science: Peer review ethics, science communication, cross-disciplinary science education, and globalization.

**Garry Smitty Grubbs II**, Associate Professor

PHD University of North Texas

Physical chemistry in the area of molecular rotational spectroscopy and gas phase chemistry; Development of spectroscopic tools for the detection of chirality, structural determination of van der Waals complexes, observation and molecular determination of actinide-containing species, and as a basis for determination of molecules in the interstellar medium; Chemistry education research aimed at delivering undergraduate level physical chemistry teaching laboratories that integrate thermodynamics, statistical mechanics, kinetics, and quantum chemistry on a budget.

**Wenyan Liu**, Assistant Research Professor

PHD New York University

Design of programmable soft materials with tailored functions; development of analytical strategies using advanced instruments (e.g., AFM, TEM, Cryo-EM, SEM, SAXS, DLS, TOC, ICP-MS, ICP-OES, GFAA, IC, HPLC, GC-ECD/FID, GC-MS, LC-MS/MS, and fluorescence spectroscopy) for applications in environmental chemistry, human health and life science et al.; Fabrication of electrochemical biosensors for medical diagnosis; Nanoparticle analysis for aerospace combustion and environmental contamination.

**Vadym Mochalin**, Associate Professor

PHD National Academy of Sciences of Ukraine

Fundamental chemistry and physics, synthesis, characterization, purification, chemical modification, computational modeling, and development of 2D and 0D materials: nanodiamond, MXenes, nanoions, nanocarbons, and other materials for applications in composites, energy storage, biology and medicine, optoelectronics, sensing, and extreme environments.

**Paul Ki-souk Nam**, Associate Professor

PHD University of Missouri-Columbia

Biofuel and bioproduct development; Microalgae and agricultural product utilization; Environmental monitoring and remediation: endocrine disruptors, emerging contaminants, aerosol/particulate matter, carbon sequestration; Supercritical fluid reaction, extraction and chromatography; Explosive and chemical agent detection and neutralization; Synthesis and characterization of enantio-enriched peptides and oligomers; Thermal treatment for material characterization and recycling.

**Manashi Nath**, Associate Professor

PHD Indian Institute of Science

Growth of functional nanowires and nanotubes of inorganic materials for energy conversion and storage, biosensor, and superconducting applications; Developing protocols for device fabrication with functional nanowire and nanotube arrays.

**V Prakash Reddy**, Professor

PHD Case Western Reserve University

Organic, physical organic, and bioorganic chemistry; Synthetic organic chemistry; Organic and bioorganic reaction mechanisms; Organofluorine chemistry; Green chemistry; Nonaqueous electrolytes for lithium ion batteries; Protein modifications; Oxidative stress; Superacids; Carbocations; Therapeutics for Alzheimer's disease and other neurological disorders; and AGE-inhibitors and -breakers in health and disease.

**Thomas Schuman**, Professor

PHD University of Alabama-Huntsville

Interface control; Non-chrome, corrosion inhibitors for aluminum alloys and steel; Adhesion promotion to plastic substrates; Organometallic nanocomposites; Development of industrial agricultural products/materials; Polymer gels for EOR applications; Transportation-infrastructure sustainability materials.

**Honglan Shi**, Research Professor

PHD Missouri S&amp;T

Environmental analysis and bioanalytical techniques, including emerging water contaminants, soil contaminants; Bioanalytical analysis, analytical instrument and test kits designs; Analytical methods development for state-of-the-art instruments including LC-MS, GC-MS, ICP-MS, ICP-OES, HPCE, HPLC, GC, and IC.

**Chariklia Sotiriou-Leventis**, Professor

PHD Michigan State University

Synthesis of nanomaterials based on aerogels: polyisocyanurate aerogels as shape memory polymers for deployable panels and biomimetic applications; Microporous carbons from phenolic aerogels as sorbent materials with exceptionally high CO<sub>2</sub> adsorption; Nanoporous metals, carbides, nitrides, borides; Supramolecular chemistry.

**Pericles Stavropoulos**, Associate Professor

PHD Imperial College, London, UK

Development of transition-metal catalysts for applications in C-H bond activation and atom/group-transfer chemistry.

**Jay A Switzer**, Curators Distinguished Professor

PHD Wayne State University

Inorganic materials chemistry; Electrochemistry; Photoelectrochemistry; Electrocatalysis; Chiral surfaces; Epitaxial growth of thin films and nanostructures; Energy conversion and storage.

**Risheng Wang**, Associate Professor

PHD New York University

Biochemistry; Structural DNA nanotechnology; Nanomaterials; Fabrication and characterization of nanostructures; DNA based biomedical and electronic applications.

**Philip D Whitefield**, Chancellor's Professor

PHD University of London, London, UK

Aerospace emissions; Chemical and physical characterization of aerosols; Aerosols generated by aerospace and other civilian and military activities; Environmental problems presented by aerosol production (e.g. local air quality at airports, rocket impact on stratospheric ozone) and their impact on power plant efficiency (e.g. evaluation of fuel additives).

**Jeffrey G. Winiarz**, Associate Professor

PHD SUNY at Buffalo

Development of polymeric photonic materials and devices using photosensitization by way of the inclusion of surface-passivated semiconductor nanocrystals.

**Klaus Woelk**, Associate Professor

PHD University of Bonn, Germany

In situ high-temperature and high-pressure NMR spectroscopy to study the chemistry of thermoplastics upcycling and the hydrothermal degradation of lignocellulosic biomass; NMR relaxometry and diffusometry to investigate fluid mobility in inhomogeneous and porous materials; Spin-spin (T2) and spin-lattice (T1) relaxation of hyperpolarized NMR spin states, toroid-cavity rotating-frame NMR microscopy.

**CHEM 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Prerequisite: Preceded or accompanied by Chem 1100 or an equivalent training program approved by S&T. Consent of instructor required.

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**CHEM 5001 Special Topics** (LEC 1.0 and LAB 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CHEM 5099 Master Research** (IND 0.0-6.0)

Master level research with the intent to lead to the preparation of a master degree thesis. Not more than six (6) credit hours allowed for graduate credit. Subject and credit to be arranged with the instructor. Preparation of a written, detailed report culminating in a thesis is required of the student. Prerequisite: Must meet departmental training requirements for laboratory safety. Consent of instructor required.

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**CHEM 5100 Laboratory Safety & Hazardous Materials** (LEC 1.0)

A systematic study of safe laboratory operations and pertinent regulations of state and federal agencies. Prerequisites: Graduate standing.

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**CHEM 5210 Fundamentals of Synthetic Organic Reactions** (LEC 3.0)

Fundamental organic reactions are discussed based on reaction mechanisms and synthetic applications emphasizing the synthon approach. Graduate students are required to demonstrate a higher level of learning on assessments. Prerequisite: Chem 2220.

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**CHEM 5220 Synthetic Organic Chemistry** (LEC 3.0)

A systematic study of organic reactions, their mechanisms and synthetic applications. Graduate students are expected to demonstrate a higher level of proficiency during assessments. Prerequisite: Chem 2220.

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**CHEM 5310 Introduction to Inorganic Chemistry** (LEC 3.0)

A study of inorganic chemistry with emphasis on physical methods. General subjects covered include: molecular structure, bonding, complexes, spectroscopy, and reaction rates. Graduate students are required to demonstrate a higher level of proficiency during assessments.

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**CHEM 5410 Advanced Chemical Thermodynamics** (LEC 3.0)

A study of the laws of thermodynamics with application to chemical systems. Emphasis is placed on partial molal functions. Credit will not be given for both Chem 5410 and Chem 4410. Prerequisites: Chem 3420.

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**CHEM 5420 Elemental Quantum Chemistry** (LEC 3.0)

A study of molecular structures and spectroscopy, statistical thermodynamics, kinetic theory, chemical kinetics, crystals, and liquids. Prerequisites: Math 2222; Physics 2135 or Physics 2111.

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**CHEM 5430 Advanced Chemical Kinetics** (LEC 3.0)

Introductory graduate treatment of special topics of physical chemistry including statistical mechanics and kinetics. Prerequisites: Chem 3430.

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**CHEM 5460 Molecular Engineering of Materials** (LEC 3.0)

This course focuses on the fundamentals of molecular engineering with an emphasis on their applications including renewable/clean energy solutions, energy storage, air/water cleaning, and optoelectronics. Topics include principles of modern physics, carbon chemistry, macromolecules, metal(covalent)-organic frameworks sol-gel processing and crystal growth. Prerequisites: Senior Standing or consent of instructor. (Co-listed with MS&E 5460).

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**CHEM 5510 Introduction to Chemical Analysis** (LEC 3.0 and LAB 1.0)

Principles and analytical applications of molecular spectroscopy, chromatographic separations, mass spectrometry, and radiochemistry. A brief overview of instrument electronics, signal generation and processing, and automated analysis is also provided. Graduate students are expected to achieve a higher level of proficiency on application and assessments compared to Chem 4510 students. Prerequisites: Chem 1100, Chem 2510, Chem 2220, Chem 3430.

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**CHEM 5610 Biochemistry** (LEC 3.0)

A resume of the important aspects of quantitative and physical chemistry in biochemical processes. General subjects covered include: proteins, nucleic acids, enzymes, carbohydrates and lipids. Credit may not be given for both Chem 5610 and Chem 4610. Prerequisite: Chem 2220.

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**CHEM 5619 Biochemistry Laboratory** (LAB 2.0)

Experiments are integrated with the lectures and cover the chemical and physical properties of proteins, enzymes, nucleic acids, carbohydrates and lipids. Credit may not be given for both Chem 5619 and Chem 4619. Prerequisites: Preceded or accompanied by Chem 5610 and Chem 1100 or an equivalent training program approved by S&T.

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**CHEM 5620 Biochemical Metabolism** (LEC 3.0)

A continuation of Chem 5610. Catabolism and anabolism of carbohydrates, lipids, proteins, and nucleic acids. Photosynthesis, oxidative phosphorylation and membranes. Credit may not be given for both Chem 5620 and Chem 4620. Prerequisite: Chem 4610 or 5610.

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**CHEM 5630 Biochemical Nanotechnology** (LEC 3.0)

This course will educate on the interdisciplinary areas of bio-nanotechnology. Student will investigate the potential of nanoscience in advanced applications including DNA/protein nanotechnology, drug delivery, environmental biosensor and emerging biotechnology industries. Credit may not be given for both Chem 5630 and Chem 4630. Prerequisite: At least junior standing.

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**CHEM 5640 Neurochemistry with Clinical Correlations** (LEC 3.0)

This course explores the chemical underpinnings of neurological phenomena. It covers the overall structure and function of neurons and glial cells, neurotransmission, signal transduction, and metabolism. A central focus of the course is relating these topics to processes such as learning and memory, as well as various pathological states. Prerequisites: Chem 4610.

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**CHEM 5710 Environmental Monitoring** (LEC 3.0)

This course provides an overview of environmental monitoring methodologies. Discussion covers thermodynamic and kinetic processes that affect chemical transport and fate in the environment. Federal environmental regulations and remediation technologies are also covered with specific examples. Credit may not be given for both Chem 5710 and Chem 4710. Prerequisites: Chem 2210, Physics 2111.

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**CHEM 5810 Introduction to Polymeric Materials** (LEC 3.0)

A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with MS&E 5810).

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**CHEM 5819 Polymer Synthesis and Characterization Lab** (LAB 1.0)

Laboratory experiments dealing with polymerization syntheses and solution, bulk and solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Credit may not be given for both Chem 5819 and Chem 4819. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810 or Chem Eng 5310, preceded or accompanied by Chem 1100 or Chem 5100 or an equivalent training program approved by S&T. (Co-listed with MS&E 5819).

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**CHEM 5850 Introduction to Coating Chemistry** (LEC 3.0)

Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Credit may not be given for both Chem 5850 and Chem 4850. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with MS&E 5850).

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**CHEM 6000 Special Problems** (IND 0.0-6.0)

Problems or reading on specific subjects or projects in the department. Consent of instructor required.

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**CHEM 6001 Special Topics** (IND 0.0 and LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CHEM 6010 Seminar** (RSD 1.0)

Discussion of current topics.

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**CHEM 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CHEM 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CHEM 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Must meet departmental requirements for instruction in laboratory safety. Consent of instructor required.

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**CHEM 6101 Introduction to Chemistry Research** (LEC 1.0)

An introduction to chemical research topics of interest to the department presented by different faculty members. Special emphasis will also be placed on a discussion of ethics, plagiarism, codes of conduct, research notebooks, publishing, and presentations. Prerequisite: Graduate Student Status.

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**CHEM 6220 Advanced Synthetic Organic Chemistry** (LEC 3.0)

A discussion of a large number of synthetically useful reactions involving enolates and enamines; nucleophilic additions to carbonyl compounds; functional group interconversions, thermal pericyclic reactions; organometallic compounds; carbocations, carbenes and free radicals as reactive intermediates; aromatic substitutions; and multistep synthesis. Prerequisite: Chem 4210 or Chem 4220.

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**CHEM 6240 Physical Organic Chemistry** (LEC 3.0)

An advanced course in theoretical organic chemistry treating molecular orbital theory, free energy relationships, transition state theory, and other fundamental topics. Prerequisite: Chem 4210.

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**CHEM 6250 Spectrometric Identification of Organic Compounds** (LEC 3.0)

Overview of MS and IR techniques in the characterization of organic compounds; CD/ORD; <sup>1</sup>H, <sup>13</sup>C, and heteronuclear NMR spectroscopy in the structural analysis; applications of APT, DEPT, <sup>1</sup>H-<sup>1</sup>H COSY, HETCOR, HMQC, HMBC, INADEQUATE, TOCSY, NOE AND NOESY, and dynamic NMR. Prerequisite: Chem 2220.

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**CHEM 6320 Solid State Chemistry** (LEC 3.0)

The aim of this course is to build a comprehensive understanding of the chemistry of solids and its application to the materials world. Emphasis will be given on the synthesis, crystal structure and various properties of solids including electrical, optical and magnetic. Students will gain knowledge about how to correlate a property with structure. Prerequisites: Chem 2310, Chem 2320, and Chem 3410.

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**CHEM 6330 Nanomaterials Synthesis, Properties and Applications** (LEC 3.0)

Chemistry of nanomaterials. Understanding the fundamentals of nanoscience and technology. Studying the different synthesis strategies for nanomaterials and their characterization. Understanding the properties of nanomaterials and their possible applications. Introducing the concept for device fabrication. Prerequisite: Chem 4310.

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**CHEM 6350 X-ray Crystallography** (LAB 2.0 and LEC 2.0)

Molecular and crystal structure determination by single crystal x-ray diffraction methods. Brief coverage of relation to neutron and electron diffraction.

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**CHEM 6360 Bioinorganic Chemistry** (LEC 3.0)

Metallobiomolecules, including metalloenzymes and other metalloproteins; oxygen carriers; iron transport and other iron proteins; copper proteins; cancer agents and cures; nitrogen-fixation, etc. Prerequisite: Chem 4310.

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**CHEM 6380 Inorganic Materials Chemistry** (LEC 3.0)

Chemical processing of solid materials. Introduction to point groups, space groups, and x-ray diffraction. Bonding in solids - from molecular orbital theory to band theory. Nonstoichiometric materials and Kroger-Vink notation. Optical and electrical properties of semiconductors. Epitaxial growth. Quantum effects in nanophase materials. Prerequisite: Chem 4310 or permission of instructor.

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**CHEM 6420 Quantum Chemistry I** (LEC 3.0)

A rigorous introduction to the fundamental concepts and principles of quantum chemistry. Application to translational, vibrational, and rotational motion; one-electron systems. Prerequisite: Chem 3420 or equivalent.

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**CHEM 6430 Chemical Kinetics** (LEC 3.0)

An introduction to the deduction of mechanisms of homogeneous chemical reactions from rate-data. Selected topics, such as photochemistry, free-radical mechanisms, catalysis, and explosion reactions. Prerequisite: Chem 3430.

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**CHEM 6450 Spectroscopy** (LEC 3.0)

Introduction to the interaction of electromagnetic radiation with matter. Emphasis on the ultraviolet, visible, and radio portions of the spectrum. Prerequisite: Chem 3420 or equivalent.

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**CHEM 6460 Advanced Molecular Engineering of Materials** (LEC 3.0)

This advanced course focuses on the fundamentals of molecular science and engineering and their applications including renewable/clean energy solutions, energy storage, and optoelectronics. Topics include principles of carbon chemistry, macromolecules, metal(covalent)-organic frameworks, sol-gel processing, crystal growth and other advanced topics. Prerequisites: Graduate Standing or consent of instructor. (Co-listed with MS&E 6460).

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**CHEM 6480 Physical Chemistry Of Surfaces** (LEC 3.0)

Adsorption at liquid interfaces and properties of surface films. Physical and chemical adsorption on solid surfaces. Catalysis.

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**CHEM 6510 Separations** (LEC 3.0)

An in-depth study of all types of analytical and preparativescale separations. A special emphasis will be placed on chromatography and chromatographic theory. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6550 Chemical Spectroscopy** (LEC 3.0)

A study of the electronic, vibrational, rotational and nuclear magnetic resonance spectra of atoms and molecules. A basic understanding of the underlying theoretical principles and the interpretations of results is stressed. Prerequisite: Chem 4510, Chem 3420 or equivalent courses.

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**CHEM 6555 Principles And Applications Of Mass Spectrometry** (LEC 3.0)

The course covers fundamental physical principles of mass spectrometry, instrumentation, interpretation of spectra, and applications in environmental, polymer, biomedical, and forensic fields. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6570 Electrochemistry** (LEC 3.0)

Introduction to the fundamentals, methods and applications of electrochemistry. Fundamentals cover the thermodynamics/kinetics of electrode reactions, and the modes of mass transport in the electrolyte. Methods cover potentiometric, amperometric, and a.c. techniques. Applications focus on analysis and study of materials. Prerequisite: Chem 3430.

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**CHEM 6580 Mass Spectrometry of Macromolecules** (LEC 3.0)

This course will provide an overview of mass spectrometric applications in biomacromolecules and synthetic polymers; particular areas of emphasis are proteomics, genomics, pharmaceutical screening, characterization of biochemical complexes and synthetic polymers. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6620 Intermediary Metabolism And Biosynthesis** (LEC 3.0)

The course covers the biosynthesis and metabolism of nucleic acids, carbohydrates, lipids and proteins. Prerequisite: Chem 4620.

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**CHEM 6650 Free Radicals In Biochemistry** (LEC 3.0)

The study of the basic principles of free radical chemistry and biochemistry. Prerequisites: Chem 2210, Chem 2220 and Bio Sci 2113.

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**CHEM 6820 Polymer Synthesis** (LEC 3.0)

The methods of organic monomer and polymer syntheses will be explored. Mechanistic and structural components, modern and current industrial methods for polymer syntheses will be discussed. Topics include linear, branched, graft, and dendritic polymers, nano-technology and macromers. Prerequisites: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; Chem 2220 or Chem 4210 or Chem 4220 or Chem 5210 or Chem 5220. (Co-listed with MS&E 6820).

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**CHEM 6840 Polymer Physical Chemistry and Analysis** (LEC 3.0)

A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; thermodynamics. (Co-listed with MS&E 6840).

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## Civil, Architectural, and Environmental Engineering

The department offers specialization in architectural engineering, construction engineering management, environmental, geotechnical, materials, structural and water resources engineering. All of the department's programs prepare graduates to provide leadership in their careers by providing a strong foundation in the fundamental and applied engineering principles. Program faculty have diverse backgrounds including civil, environmental, mechanical, aerospace, architectural, and chemical engineering. All programs include strong design and research components, while having the flexibility to tailor curricula to individual needs. Faculty in all programs collaborate extensively with faculty and researchers from other departments, at Missouri S&T and elsewhere. The Civil, Architectural, and Environmental Engineering Department's motto is "Change the World," and through our cutting edge educational programs and research, our graduates are well prepared to meet that goal.

Recent and ongoing funded graduate student research includes: advanced infrastructure materials, natural hazard mitigation for structures, smart cities, river mechanics, constitutive modeling of reinforced and prestressed structures, blast- and impact- protection of critical infrastructure, real-time instrumentation of civil infrastructure, phytoremediation of organic contaminants, aerosol generation and transport, compact low-energy wastewater treatment, green infrastructure, sustainable pavement systems, nanomaterials design and use in infrastructure, durability of concrete, climate adaptation of infrastructure, remote sensing for geo engineering and environmental assessments, and 3D printing of infrastructure materials.

The basic prerequisite for admission to graduate study in the department is a Bachelor of Science degree in Engineering from an ABET accredited school or equivalent. Students who have a degree from a non-accredited school, or hold a Bachelor of Science degree in a field other than engineering, may be required to take engineering prerequisites to prepare for graduate courses. Specific prerequisites will depend on the student's academic background and intended area of specialization. Degree programs offered are the master of science in civil engineering (MSCE), master of science in environmental engineering (MSEnVE), the doctor of engineering (DE), and the doctor of philosophy (PhD).

The MS degrees are available on campus online via streaming video for place-bound students. Also, the department offers online graduate certificate programs in contemporary structural engineering, geoenvironmental engineering, infrastructure renewal, and project engineering and construction management. Advanced graduate offerings in advanced materials for sustainable infrastructure, surface water resources, and building systems engineering.

The department is housed in Butler-Carlton Hall, which is also home to outstanding research and teaching facilities, including: the high-bay Structural Engineering Research Laboratory (SERL), the Reese Bituminous Materials Laboratory, the Clayco Advanced Construction and Materials Laboratory (ACML), concrete materials laboratory, System and Process Assessment Research Laboratory (SPAR), geotechnical laboratory, Mathes Environmental Research Laboratories, and water resources laboratory. The Baker Greenhouse is used to study environmental research on plants for controlling groundwater pollution, wetlands and air pollution. All laboratories are equipped with the latest testing, data acquisition and control equipment. The department has its own machine and electronics shops and trained technical staff used for

design, construction and maintenance of specialized mechanical and electronic testing equipment needed to support research and teaching.

The department is also home to the Center for Research in Energy and Environment (CREE), the Wei-Wen Yu Center for Cold-Formed Steel Structures (CCFSS), and is active in three separate University Transportation Centers as well as having active partnerships with the Center for Infrastructure Engineering Studies (CIES), the Center for Intelligent Infrastructure (CII) and the Missouri Local Training and Resource Center (MLTRC).

The mission of the Center for Research in Energy and Environment (CREE) is to establish the infrastructure and coordinated faculty base to conduct a wide range of large-scale externally-funded research initiatives designed to protect public health from emerging contaminants and improve our energy systems from generation to utilization. The center helps a diverse group of researchers from across the university to share resources necessary to tackle national and global energy and environmental challenges.

The Center for Intelligent Infrastructure (CII) aims to transform currently disparate design, construction, and operation phases of cyber-physical infrastructures into an open-source, cloud-based application featuring computer simulations of physical infrastructures overlaid with cyber and social infrastructure. Such a digital infrastructure initiative enables grand-scale fundamental and convergent research on the integrated design-build-operation process of infrastructure.

The Center for Infrastructure Engineering Studies (CIES) is an interdisciplinary research center that provides leadership in research and education aimed at solving the problems affecting the nation's aging infrastructure. CIES seeks to be the primary conduit for communication among faculty members on the Missouri S&T campus interested in infrastructure studies through the following mechanisms: interdisciplinary R&D, student education, technology transfer, preparing major infrastructure proposals.

The University Transportation Center program was established to advance United States technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence. The theme of this center is to address national needs in the areas of transportation infrastructure focusing on advanced materials, infrastructure resilience and non-destructive testing (NDT) technologies.

The mission of the Wei-WenYu Center for Cold-Formed Steel Structures Center (CCFSS) is to provide an integrated approach for handling research, teaching, engineering education, technical services, and professional activity. The center brings together the technical resources of interested parties, i.e., university researchers, steel producers, product manufacturers, consultants, building officials, government agencies, and others with a common goal of continued improvement of cold-formed steel design and construction.

The Missouri Local Training and Resource Center (MLTRC) provides a resource center available for use by local agencies throughout the state of Missouri. Its regular activities include the Proactive Training and Customized Transportation Education Programs (PTP and CTEP, respectively), ongoing development of transportation lending and distribution lending libraries, management of MoDOT's Cooperative Purchasing Program, production of a quarterly newsletter, and functioning as a transportation technical assistance resource for individuals and agencies around the state.

## Contemporary Structural Engineering Certificate

Choose one course from each of the following three groups (analysis, design, and structural system) and the fourth course from any of the three groups.

### I. Structural Analysis Courses:

CIV ENG 5203/ ARCH ENG 5203	Applied Mechanics In Structural Engineering
CIV ENG 5205/ ARCH ENG 5205	Structural Analysis II
CIV ENG 5207/ ARCH ENG 5207	Computer Methods of Structural Analysis
CIV ENG 5208/ ARCH ENG 5208	Structural Dynamics

### II. Structural Design Courses:

CIV ENG 5210/ ARCH ENG 5210	Advanced Steel Structures Design
CIV ENG 5220/ ARCH ENG 5220	Advanced Concrete Structures Design
CIV ENG 5222/ ARCH ENG 5222	Prestressed Concrete Design
CIV ENG 5231/ ARCH ENG 5231	Infrastructure Strengthening with Composites

### III. Structural System Courses:

CIV ENG 5206/ ARCH ENG 5206	Low-Rise Building Analysis and Design
CIV ENG 6213	Advanced Design in Steel and Lightweight Structures
AERO ENG 5234/ MECH ENG 5234	Stability of Engineering Structures

### IV. Combined Structural Courses:

CIV ENG 5203/ ARCH ENG 5203	Applied Mechanics In Structural Engineering
CIV ENG 5205/ ARCH ENG 5205	Structural Analysis II
CIV ENG 5206/ ARCH ENG 5206	Low-Rise Building Analysis and Design
CIV ENG 5207/ ARCH ENG 5207	Computer Methods of Structural Analysis
CIV ENG 5208/ ARCH ENG 5208	Structural Dynamics
CIV ENG 5210/ ARCH ENG 5210	Advanced Steel Structures Design
CIV ENG 5220/ ARCH ENG 5220	Advanced Concrete Structures Design
CIV ENG 5222/ ARCH ENG 5222	Prestressed Concrete Design
CIV ENG 5231/ ARCH ENG 5231	Infrastructure Strengthening with Composites
CIV ENG 6213	Advanced Design in Steel and Lightweight Structures
AERO ENG 5234/ MECH ENG 5234	Stability of Engineering Structures

## Geoenvironmental Engineering Certificate

A minimum of two of the following geotechnical courses must be taken:

CIV ENG 5744	Geosynthetics in Engineering
CIV ENG 5715	Intermediate Soil Mechanics
CIV ENG 5729	Foundation Engineering II

A minimum of two of the following environmental courses must be taken:

CIV ENG 5360	Water Resources And Wastewater Engineering
CIV ENG 5640	Environmental Law And Regulations
CIV ENG 5630	Remediation of Contaminated Groundwater and Soil
CIV ENG 5650	Public Health Engineering
CIV ENG 5670	Solid Waste Management
CIV ENG 5642	Sustainability, Population, Energy, Water, and Materials

## Geotechnical Earthquake Engineering Certificate

The following courses are required:

CIV ENG 5716	Geotechnical Earthquake Engineering
CIV ENG 6713	Dynamics of Earth Materials

Two of the following three courses are required:

CIV ENG 5715	Intermediate Soil Mechanics
CIV ENG 5729	Foundation Engineering II
CIV ENG 6712	Computer Modeling in Geotechnical Engineering

## Infrastructure Renewal Certificate

Two of the following courses are required:

CIV ENG 5231	Infrastructure Strengthening with Composites
AERO ENG 5282	Introduction to Composite Materials & Structures
CIV ENG 5744	Geosynthetics in Engineering

One of the following courses is required:

CIV ENG 5210	Advanced Steel Structures Design
CIV ENG 5220	Advanced Concrete Structures Design
CIV ENG 5222	Prestressed Concrete Design

One of the following courses is required:

CIV ENG 5208	Structural Dynamics
CIV ENG 5445	Construction Methods
CIV ENG 5729	Foundation Engineering II
AERO ENG 6284	Analysis of Laminated Composite Structures

## Project Engineering and Construction Management Certificate

(Offered in both civil engineering and engineering management disciplines)

Two of the following courses are required:

CIV ENG 5445	Construction Methods
CIV ENG 5449	Engineering and Construction Contract Specifications
CIV ENG 6442	Construction Administration, Planning and Control
CIV ENG 6445	Advanced Construction Engineering

Two of the following courses are required:

ENG MGT 5111	Management for Engineers and Scientists
ENG MGT 5210	Economic Decision Analysis

ENG MGT 5320 Project Management

ENG MGT 6323 Global Project Management

**Magdy Abdelrahman, Professor**<sup>1</sup>

PHD University of Illinois at Urbana-Champaign  
Interdisciplinarity aspects of asphalt technology, modified asphalt binders, recycled materials in pavement application, infrastructure sustainability of pavement design, materials and performance.

**Stuart W Baur, Associate Professor**<sup>4</sup>

PHD University of Missouri-Rolla  
Integrated building systems, advanced technologies in building systems, green construction, rehabilitation of historic structures, materials and methods of construction.

**Joel G Burken, Curators Distinguished Professor**<sup>1,5</sup>

PHD University of Iowa  
Phytoremediation of organic contaminants and heavy metals, green infrastructure, remote sensing and computer visualization of plant stress for contaminant delineation and vegetative restoration.

**Genda Chen, Professor**<sup>1</sup>

PHD State University of New York at Buffalo  
Infrastructure preservation and resilience, structural health monitoring, structural (robotic) dynamics and control, structural mechanics and deterioration, multi-hazard assessment and mitigation.

**Islam El-adaway, Professor**<sup>1</sup>

PHD Iowa State University  
Construction engineering and management, modeling and simulation, sustainable infrastructure management, resilient hazard management, energy management, contractual and dispute management, decision and risk management.

**Mohamed Abdelmonem ElGawady, Professor**

DE Swiss Federal Institute of Technology  
Reinforced concrete and masonry structures, prestressed concrete and masonry, bridges, segmental bridge construction, accelerated bridge construction, earthquake engineering, impact protection devices, tire derived aggregate, geopolymer, rubberized chip seal, rubberized concrete, and sustainable materials.

**Dimitri Feys, Associate Professor**

PHD Ghent University, Belgium  
Behavior of fresh cement-based materials, including mixing and placement, in particular pumping; advanced rheology of cement-based materials, focusing on measurement protocols, interactions with hydration and applications for digital fabrication; rheology of other complex materials and suspensions, and fluid mechanics.

**Mark W Fitch, Associate Professor**

PHD University of Texas-Austin  
Membrane bioreactors, constructed wetlands/biochemical reactors for metals removal, metal immobilization, nutrient removal by floating treatment wetlands in urban waterbodies.

**William Gillis, Assistant Teaching Professor**<sup>1,6</sup>

PHD Missouri University of Science and Technology  
Building systems, green building design and construction, and building commissioning.

**XianBiao Hu, Assistant Professor**

PHD University of Arizona  
Smart transportation systems, connected and autonomous vehicles, electric vehicles, transportation big data analytics, traffic flow and system modeling.

**Kamal Khayat, Professor**<sup>1</sup>

DE University of California-Berkeley  
Advanced cement-based materials, including high-performance concrete and self-consolidating concrete, concrete rheology and repair of infrastructure.

**Nicholas Ali Libre, Assistant Teaching Professor**

PHD University of Tehran, Iran  
Teaching innovations and educational technologies, numerical simulation and computational mechanics, meshfree methods, development and characterization of cement based construction materials for infrastructure systems, additive manufacturing with cement based fiber reinforced composites (FRC).

**Jenny Liu, Professor**<sup>1</sup>

PHD Texas A&M University  
Engineering characterization and modeling of civil infrastructure materials, sustainable materials and resilient infrastructure adapting to climate change and extreme events, pavement design, testing, and evaluation, pavement preservation, and non-destructive testing.

**Hongyan Ma, Assistant Professor**

PHD Hong Kong University of Science and Technology  
Future cements, solid waste upcycling, energy storage and massive CO<sub>2</sub> sequestration, smart systems for NDT/E, material characterization, multi-scale modeling (from molecular dynamics to macroscopic FEM) of concrete, and mechanisms and mitigation of concrete deterioration.

**Cesar Mendoza, Associate Professor**

PHD Colorado State University  
Sediment transport, river mechanics, environmental fluid mechanics, hydrodynamics, and mathematical modeling.

**John J Myers, Professor**<sup>1</sup>

PHD University of Texas-Austin  
Advanced concrete structural behavior and durability performance (PC and RC) including HPC, HSC, HS-SCC, UHPC, HVFA-SCC and sustainable concretes; development of infrastructure systems and monitoring techniques; fiber-reinforced polymers (FRP) and fiber-reinforced cementitious matrix (FRCM) in structural repair and strengthening applications with an emphasis related to structural behavior, blast resistance, bond, substrate characterization, and durability performance.

**Daniel B Oerther, Professor**<sup>1,5</sup>

PHD University of Illinois-Urbana  
Environmental biotechnology, urban sustainability, global development, ensuring universal access to water and sanitation, combating the obesity epidemic, and eliminating extreme poverty.

**Guney Olgun, Assistant Professor**

PHD Virginia Polytechnic Institute and State University  
Energy geotechnology, geothermal foundations and shallow geothermal systems, geotechnical earthquake engineering, soil improvement, liquefaction, granular geomechanics, fluvial erosion, and disaster resilience.

**William P Schonberg**, Professor<sup>1</sup>

PHD Northwestern University

Assistant chair for distance education and remote programs; armor/anti-armor, penetration mechanics, spacecraft shielding against meteoroid and orbital debris impacts, hypervelocity impact phenomena, building failure and collapse, design and construction of Moon and Mars habitats.

**William Eric Showalter**, Teaching Professor<sup>1,6</sup>

PHD Purdue University

Construction engineering and management, cost effectiveness, sustainable design and construction.

**Lesley Haynes Sneed**, Associate Professor<sup>1</sup>

PHD Purdue University

Reinforced and prestressed concrete structural members and systems, structural models and experimental methods, innovative methods of repair and strengthening of structures subjected to seismic loading or other extreme hazards, evaluation of existing structures, design codes for structural concrete.

**Sanjay Tewari**, Assistant Teaching Professor

PHD Texas A&amp;M University

Capacitive deionization, electro-kinetics and soil remediation, electro-coagulation, desalination, sustainability, hydrogeology and water quality challenges, GIS applications for climate change and resiliency of infrastructure.

**Jeffery S Thomas**, Associate Teaching Professor<sup>1</sup>

PHD Missouri University of Science &amp; Technology

Mechanical characterization and engineering mechanics.

**Jianmin Wang**, Professor<sup>1</sup>

PHD University of Delaware

Sustainable wastewater treatment and reuse, nanoparticle ecotoxicity, fate and transport of heavy metals in environment.

**Yang Wang**, Assistant Professor

PHD Washington University, St. Louis

Air quality and monitoring, aerosol instrumentation, climate impact of aerosols, combustion synthesis of nanoparticles, and low-cost air quality sensors.

**Chenglin Wu**, Assistant Professor

PHD, PHD University of Texas-Austin, Missouri University of Science and Technology

Nano-mechanics, nanomaterials, nanomanufacturing; sensing and energy materials; machine learning assisted material design and characterization; and 3D printing infrastructural materials.

**Guirong Yan**, Assistant Professor

PHD Harbin Institute of Technology, China

Computational Wind Engineering (CFD simulations of tornadoes and hurricanes); improvement of risk awareness and decision-making of natural hazards through virtual reality animation, social science, psychology and behavior finance; wind hazard mitigation and community resilience by structural health monitoring and condition assessment.

**Xiong Zhang**, Associate Professor<sup>1</sup>

PHD Texas A&amp;M University

Advanced testing techniques for geo-material characterization, modeling of couple hydro-chem-thermo-mechanical behavior of geo-materials, numerical methods and modeling, soil structure interaction, soil stabilization and ground improvement, frozen ground engineering, climatic effects on infrastructure, and remote sensing for geo-engineering applications.

**ARCH ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**ARCH ENG 5001 Special Topics** (LAB 1.0 and LEC 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ARCH ENG 5203 Applied Mechanics In Structural Engineering** (LEC 3.0)

A study of basic relationships involved in the mechanics of structures. Topic include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge building floors and shell roofs. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Civ Eng 5203).

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**ARCH ENG 5205 Structural Analysis II** (LEC 3.0)

Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 3201 or Arch Eng 3201. (Co-listed with Civ Eng 5205).

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**ARCH ENG 5206 Low-Rise Building Analysis And Design** (LEC 3.0)

Characterization of various design loads, load combinations, general methodology of structural designs against lateral loads, code-oriented design procedures, distribution of lateral loads in structural systems, application of the International Building Code in design of loadbearing wall systems, building frame system and moment-resisting frame systems. Prerequisite: Preceded and/or accompanied by Civ -Arch Eng 3210 or Civ-Arch Eng 3220. (Co-listed with Civ Eng 5206).

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**ARCH ENG 5207 Computer Methods of Structural Analysis** (LEC 3.0)

Force and displacement matrix methods and computer methods applied to structural analysis. Analysis of indeterminate structures such as continuous beams, and two and three dimensional frames and trusses. Analysis of indeterminate structures involving temperature and support settlements effects using computer methods formulation. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Civ Eng 5207).

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**ARCH ENG 5208 Structural Dynamics** (LEC 3.0)

This course deals with fundamental concepts and structural responses under dynamic loads. Hand calculations and computer methods are developed. Specific topics include resonance, beating phenomenon, equation of motion, dynamic properties, frequencies and mode shapes, and modal and Ritz analyses. Prerequisites: Mech Eng 2350 or equivalent; Civ/Arch Eng 3201 or equivalent. (Co-listed with Civ Eng 5208).

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**ARCH ENG 5210 Advanced Steel Structures Design** (LEC 3.0)

The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool aid in the design will be emphasized. Prerequisite: Arch Eng 3210 with a grade of "C" or better. (Co-listed with Civ Eng 5210).

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**ARCH ENG 5220 Advanced Concrete Structures Design** (LEC 3.0)

The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Arch Eng 3220 with a grade of "C" or better. (Co-listed with Civ Eng 5220).

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**ARCH ENG 5222 Prestressed Concrete Design** (LEC 3.0)

Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Arch Eng 3220 with a grade of "C" or better. (Co-listed with Civ Eng 5222).

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**ARCH ENG 5231 Infrastructure Strengthening with Composites** (LEC 3.0)

The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of existing members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Arch Eng / Civ Eng 3201, Arch Eng / Civ Eng 3220. (Co-listed with Civ Eng 5231).

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**ARCH ENG 5260 Analysis And Design Of Wood Structures** (LEC 3.0)

A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisite: Arch Eng 3201 with a grade of "C" or better. (Co-listed with Civ Eng 5260).

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**ARCH ENG 5270 Structural Masonry Design** (LEC 3.0)

Review of the theory and practice of analyzing low-rise masonry structures, materials and assembly types, constructability considerations, structural masonry components, repair and strengthening, and model code requirements to ensure adequate load resisting buildings. Prerequisites: Arch Eng 3201 or Civ Eng 3201. (Co-listed with Civ Eng 5270).

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**ARCH ENG 5442 Construction Planning and Scheduling Strategies** (LEC 3.0)

The goal of this course is to assist participants in gaining an understanding of schedule control techniques and the application of tools such as Primavera Software. Content areas to be addressed include: development of baseline schedules, progress monitoring and updating, recovery schedules, resource application and leveling. Prerequisite: Civ Eng or Arch Eng 4448. (Co-listed with Civ Eng 5442).

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**ARCH ENG 5445 Construction Methods** (LEC 3.0)

Introduction to construction planning selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5445).

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**ARCH ENG 5446 Management Of Construction Costs** (LEC 3.0)

Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5446).

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**ARCH ENG 5448 Green Engineering: Analysis of Constructed Facilities** (LEC 3.0)

Environmentally sound design and construction practices. Includes design issues, material selection and site issues that can reduce the impact on the environment caused by the construction process. LEED certification covered in depth. Prerequisites: Civ Eng 4448 or Arch Eng 4448; and Junior Standing. (Co-listed with Civ Eng 5448).

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**ARCH ENG 5449 Engineering and Construction Contract Specifications** (LEC 3.0)

Legal and business aspects of contracts and contracting procedure in the construction industry. Topics include formulation of contracts in common law, engineering services contracts, and construction project contract documents and contract administration issues. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5449).

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**ARCH ENG 5642 Sustainability, Population, Energy, Water, and Materials** (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Env Eng 5642 and Civ Eng 5642).

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**ARCH ENG 5665 Indoor Air Pollution** (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Civ Eng 5665 and Env Eng 5665).

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**ARCH ENG 5729 Foundation Engineering II** (LEC 3.0)

Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Civ Eng 4729 with a grade of "C" or better. (Co-listed with Civ Eng 5729).

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**ARCH ENG 5820 Building Lighting Systems** (LEC 3.0)

Design and specifications for interior and exterior building illumination systems. Work includes study of applicable NFPA 70 (NEC) and related building codes. Prerequisites: Senior standing and Physics 2135.

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**ARCH ENG 5850 Residential Renewable Energy Systems** (LAB 1.0 and LEC 2.0)

Applications of renewable energy systems for residential use will be covered, including system selection and sizing. Economic and life cycle analysis will be used to evaluate solar, geothermal and wind power systems. Prerequisites: Senior standing and consent of instructor, or Mech Eng 2527 or Civ Eng 3842.

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**ARCH ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ARCH ENG 6801 Advanced Concrete Science and Technology** (LEC 3.0)

The course covers advanced notions of concrete science and technology. It discusses various aspects related to cement manufacturing, cement hydration and microstructure, use of supplementary cementitious materials and chemical admixtures, rheology and workability, mechanical properties, dimensional stability, durability, and sustainability of concrete. Prerequisites: Civ Eng 5113 or equivalent; or consent of the instructor with Graduate Standing. (Co-listed with Civ Eng 6801).

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**CIV ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CIV ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CIV ENG 5010 Seminar** (LEC 1.0)

Discussion of current topics. Prerequisite: Senior standing.

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**CIV ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Elec Eng 5070).

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**CIV ENG 5112 Bituminous Materials** (LEC 2.0 and LAB 1.0)

Properties, types, and grades of bituminous materials are presented. Emphasis is placed on usage, distress, surface treatment design, and asphalt concrete mix properties, behavior, design manufacture, and construction. Prerequisite: Preceded or accompanied by Civ Eng 3116.

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**CIV ENG 5113 Composition And Properties Of Concrete** (LEC 3.0)

Properties of plastic and hardened concrete and the influence of cements, aggregates, water and admixtures upon these properties. The microstructure of cement gel and other factors are related to the behavior of hardened concrete under various types of loading and environments, drying shrinkage, creep and relaxation, fatigue, fracture, and durability. Introduction to statistical quality control of concrete production. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

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**CIV ENG 5117 Asphalt Pavement Design** (LEC 3.0)

Structural design of flexible pavements including loading characteristics, properties of pavement components, stress distribution, and the effects of climatic variables on design criteria. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

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**CIV ENG 5118 Smart Materials And Sensors** (LEC 2.0 and LAB 1.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior Standing and Math 3304. (Co-listed with Aero Eng 5229, Mech Eng 5229 and Elec Eng 5270).

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**CIV ENG 5156 Pavement Design** (LEC 3.0)

Principles of flexible and rigid pavement design including stress analysis, load and environmental effects and material characteristics; Introduction to AASHTO, PCA, AI, FAA, MEPDG, and other design methods; design of overlays and drainage system; pavement performance evaluation and rehabilitation techniques. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

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**CIV ENG 5203 Applied Mechanics In Structural Engineering** (LEC 3.0)

A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge, building floors, and shell roofs. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5203).

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**CIV ENG 5205 Structural Analysis II** (LEC 3.0)

Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 3201 or Arch Eng 3201. (Co-listed with Arch Eng 5205).

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**CIV ENG 5206 Low-Rise Building Analysis and Design** (LEC 3.0)

Characterization of various design loads, load combinations, general methodology of structural designs against lateral loads, code-oriented design procedures, distribution of lateral loads in structural systems, application of the International Building Code in design of loadbearing wall systems, building frame system and moment-resisting frame systems. Prerequisite: Preceded and/or accompanied by Civ -Arch Eng 3210 or Civ-Arch Eng 3220. (Co-listed with Arch Eng 5206).

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**CIV ENG 5207 Computer Methods of Structural Analysis** (LEC 3.0)

Force and displacement matrix methods and computer methods applied to structural analysis. Analysis of indeterminate structures such as continuous beams, and two and three dimensional frames and trusses. Analysis of indeterminate structures involving temperature and support settlements effects using computer methods formulation. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5207).

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**CIV ENG 5208 Structural Dynamics** (LEC 3.0)

This course deals with fundamental concepts and structural responses under dynamic loads. Hand calculations and computer methods are developed. Specific topics include resonance, beating phenomenon, equation of motion, dynamic properties, frequencies and mode shapes, and modal and Ritz analyses. Prerequisites: Mech Eng 2350 or equivalent; Civ/Arch Eng 3201 or equivalent. (Co-listed with Arch Eng 5208).

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**CIV ENG 5209 Wind Engineering** (LEC 3.0)

Introduction of wind engineering to advanced undergraduate and entry-level graduate students through structural engineering and atmospheric science fundamentals. Prerequisites: A grade of "C" or better in Civ Eng 3201. (Co-listed with Arch Eng 5001).

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**CIV ENG 5210 Advanced Steel Structures Design** (LEC 3.0)

The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3210 with a grade of "C" or better. (Co-listed with Arch Eng 5210).

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**CIV ENG 5220 Advanced Concrete Structures Design** (LEC 3.0)

The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5220).

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**CIV ENG 5222 Prestressed Concrete Design** (LEC 3.0)

Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5222).

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**CIV ENG 5231 Infrastructure Strengthening with Composites** (LEC 3.0)

The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of existing members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Civ Eng / Arch Eng 3201, Civ Eng / Arch Eng 3220. (Co-listed with Arch Eng 5231).

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**CIV ENG 5250 Air Transportation** (LAB 1.0 and LEC 2.0)

Runway configuration, airfield capacity, geometrics and terminal layout and design. Aircraft performance; navigation and air traffic control; airport planning and design; airline operations; aviation systems planning. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5260 Analysis And Design Of Wood Structures** (LEC 3.0)

A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5260).

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**CIV ENG 5270 Structural Masonry Design** (LEC 3.0)

Review of the theory and practice of analyzing low-rise masonry structures, materials and assembly types, constructability considerations, structural masonry components, repair and strengthening, and model code requirements to ensure adequate load resisting buildings. Prerequisites: Arch Eng 3201 or Civ Eng 3201. (Co-listed with Arch Eng 5270).

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**CIV ENG 5330 Unsteady Flow Hydraulics** (LEC 3.0)

The study of unsteady flow and its effect on closed water systems and in open channels. Prerequisites: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5331 Hydraulics Of Open Channels** (LEC 3.0)

The phenomena accompanying the flow of water in open channels, such as uniform and varied flow, critical conditions, backwater curves, hydraulic jump, hydraulic drop and applications are studied in detail. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5332 Transport Processes in Environmental Flows** (LEC 3.0)

Dynamics, mixing and contaminant transport in surface water bodies, including rivers and lakes. Buoyancy modifications to the mixing and dynamics of pollutant discharges and surface water bodies. Transport of sediments. Exchange processes at the air/water and sediment/water interfaces. Prerequisite: At least a "C" in Civ Eng 3330.

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**CIV ENG 5333 Intermediate Hydraulic Engineering** (LEC 3.0)

Application of fluid mechanics principles to the design. Kinematics of fluid motion, conservation of mass, linear and angular momentum, and energy. Requirements for similarity of fluid flow. Introduction to dynamics of fluid flows and viscous incompressible flows. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5335 Water Infrastructure Engineering** (LAB 1.0 and LEC 2.0)

Fundamental principles underlying comprehensive water infrastructure development; sanitary sewers, sanitary treatment facilities, stormwater sewers, stormwater detention, water power development, and hydraulic structures. The student is responsible for the planning and design of a water infrastructure development project. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5337 River Mechanics And Sediment Transport** (LEC 3.0)

Formation of rivers and the laws governing river regulation and improvements, including navigation and flood protection. Principles governing sediment transport. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5338 Hydrologic Engineering** (LEC 3.0)

A study of current up-to-date hydrologic techniques involving design of hydrologic input for bridges, culverts, reservoirs. Techniques involve extreme value statistics, model hydrographs, routing, etc. Prerequisite: Civ Eng 3334 with a grade of "C" or better.

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**CIV ENG 5360 Water Resources And Wastewater Engineering** (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal/systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Env Eng 5360).

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**CIV ENG 5404 Legal Aspects Of Boundary Surveying** (LEC 3.0)

The U.S. Public Land Survey System (USPLSS): original GLO survey instructions and procedures. Resurveys on the USPLSS law, standards, procedures with emphasis on Missouri. Rights in real property; statute, case and administrative law applied to boundaries. Simultaneous and sequence conveyances. Unwritten rights in real property. Riparian boundaries. Writing and interpreting boundary descriptions. Land surveyor duties and responsibilities. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5406 Surveying Systems** (LEC 3.0)

Celestial observations for azimuths. Introduction to State Plane Coordinate systems. Theory and calculations. Route surveying and geometrics, horizontal, spiral and vertical curves. Surveying aspects of residential and commercial subdivision design: lot layout, rights of way, easements, setbacks, platting, planning and zoning constraints, application of surveying software. Instrumentation: total stations, electronic levels, instrument calibrations. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5441 Professional Aspects Of Engineering Practice** (LEC 3.0)

A study of engineering registration laws, regulations, rules of professional responsibility and standards of practice. Review of causative factors of selected failures and their relationship to professional responsibility. Prerequisite: Senior standing.

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**CIV ENG 5442 Construction Planning and Scheduling Strategies** (LEC 3.0)

The goal of this course is to assist participants in gaining an understanding of schedule control techniques and the application of tools such as Primavera Software. Content areas to be addressed include: development of baseline schedules, progress monitoring and updating, recovery schedules, resource application and leveling. Prerequisite: Civ Eng or Arch Eng 4448. (Co-listed with Arch Eng 5442).

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**CIV ENG 5445 Construction Methods** (LEC 3.0)

Introduction to construction planning, selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5445).

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**CIV ENG 5446 Management Of Construction Costs** (LEC 3.0)

Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisites: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5446).

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**CIV ENG 5448 Green Engineering: Analysis of Constructed Facilities** (LEC 3.0)

Environmentally sound design and construction practices. Includes design issues, material selection and site issues that can reduce the impact on the environment caused by the construction process. LEED certification covered in depth. Prerequisites: Civ Eng 4448 or Arch Eng 4448; and Junior Standing. (Co-listed with Arch Eng 5448).

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**CIV ENG 5449 Engineering and Construction Contract Specifications** (LEC 3.0)

Legal and business aspects of contracts and contracting procedure in the construction industry. Topics include formulation of contracts in common law, engineering services contracts, and construction project contract documents and contract administration issues. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5449).

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**CIV ENG 5451 Information Technology Applications in the Construction Industry** (LEC 3.0)

Study of IT in construction industry including building information modeling and mobile sensing. Topics will include: collaborative design, clash detection, level of development, BIM contracts, automated code checking, and finally, information systems specific functions such as estimating, scheduling and cost control, lean, and integrated project delivery. Prerequisites: Civ Eng 2451.

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**CIV ENG 5452 Pre-Project Planning and Feasibility Studies** (LEC 3.0)

Overview of the studies and tools needed to make go-ahead decisions for construction projects including assimilation of client needs, surveys of project area and infrastructure conditions, scope validation, team development, project planning and cost estimation, and financial feasibility. Prerequisites: Civ Eng 4448 or both Eng Mgt 3320 and Eng Mgt 1210.

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**CIV ENG 5453 Logistics for Construction Industry** (LEC 3.0)

Overview of construction site layout, team organization, information flow, and complexities as related to: productivity improvement approaches, data gathering for analysis of construction operations, process innovation, and safety practices. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5454 Construction Technology for High-Rise Buildings** (LEC 3.0)

Overview of latest construction practices and processes for high-rise buildings from foundation to roof including advanced methods, materials, equipment and systems used for the construction of high-rise buildings, as well as the associated principles of sustainable construction. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5455 Construction Industry Best Practices** (LEC 3.0)

Overview of the best practices developed by the Construction Industry Institute (CII), and how they are implemented by the leading owners and contractors in the construction industry. Guest lecturers include CII staff and visiting industry subject matter experts. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5510 Geometric Design Of Highways** (LEC 2.0 and LAB 1.0)

Development and applications of concepts of geometric design for rural and urban highways. Design controls and criteria; elements of design, including sight distance, horizontal and vertical alignment; cross-section elements; highway types; intersection design elements; types of interchanges and interchange design elements; grade separations and clearance; development of visual elements. Prerequisite: Civ Eng 3500 with grade of "C" or better.

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**CIV ENG 5513 Traffic Engineering** (LEC 3.0)

Introduction to multimodal transportation systems and the factors that influence the planning, design, control, operation and safety of the systems will be made. This course will also include the discussion of Intelligence Transportation Systems and how emerging technologies are changing transportation systems. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5515 Advanced Traffic Operations and Capacity Analysis** (LEC 3.0)

This course will introduce students to advanced traffic operation and capacity analysis as applied to an urban highway network. It will focus on the operations and management of freeway and arterials where a signalized intersection is one of the key elements affecting traffic flow operation and determining highway capacity. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5605 Environmental Systems Modeling** (LEC 3.0)

Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Env Eng 5605).

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**CIV ENG 5619 Environmental Engineering Design** (LEC 2.0 and LAB 1.0)

Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Env Eng 5619).

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**CIV ENG 5630 Remediation of Contaminated Groundwater and Soil** (LEC 2.0 and LAB 1.0)

Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Env Eng 5630).

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**CIV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design** (LEC 3.0)

Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisites: Civ Eng 3615 or Env Eng 3615.(Co-listed with Env Eng 5635).

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**CIV ENG 5640 Environmental Law And Regulations** (LEC 3.0)

This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, AND CERCLA. Case studies will be emphasized. (Co-listed with Env Eng 5640).

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**CIV ENG 5642 Sustainability, Population, Energy, Water, and Materials** (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Env Eng 5642 and Arch Eng 5642).

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**CIV ENG 5650 Public Health Engineering** (LEC 3.0)

A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with a grade of "C" or better. (Co-listed with Env Eng 5650).

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**CIV ENG 5660 Introduction To Air Pollution** (LEC 3.0)

Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5660).

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**CIV ENG 5662 Air Pollution Control Methods** (LEC 3.0)

Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5662).

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**CIV ENG 5665 Indoor Air Pollution** (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Env Eng 5665 and Arch Eng 5665).

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**CIV ENG 5670 Solid Waste Management** (LEC 3.0)

A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Env Eng 5670).

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**CIV ENG 5702 Geomatics** (LEC 3.0)

Horizontal and vertical geodetic datums and networks. Theory, calculations and applications of State Plane Coordinate Systems. Introduction to Geographic and Land Information Systems: hardware and software issues; data quality and accuracy; resource, environmental, cadastral and governmental applications; databases; GIS/LIS trends. Introduction to Global Positioning Systems (GPS): Project planning, data collection, data processing and network adjustment applications, Kinematic and RealTime GPS applications, hardware and software options and costs. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5715 Intermediate Soil Mechanics** (LEC 3.0)

General principles of soil mechanics and their applications, including mineralogy, soil structure, flow through porous media, shear strength, slope stability and consolidation. Prerequisites: Civ Eng 3715 with grade of "C" or better.

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**CIV ENG 5716 Geotechnical Earthquake Engineering** (LEC 3.0)

Geotechnical earthquake hazards and mitigations, damage to structures, plate tectonics, seismicity, wave propagation, characterization of ground motions, theory of vibrations (1-DOF), effect of local soil conditions on ground response, development of design ground motions, liquefaction, dynamic lateral earth pressures and slope stability/deformation. Prerequisites: Civ Eng 3715 with a grade of "C" or better.

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**CIV ENG 5729 Foundation Engineering II** (LEC 3.0)

Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Civ Eng 4729 with a grade of "C" or better. (Co-listed with Arch Eng 5729).

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**CIV ENG 5744 Geosynthetics in Engineering** (LEC 3.0)

Geotechnical principles are applied to design of geosynthetic systems for foundation support, earth retention, drainage, and disposal of hazardous conventional wastes. Geosynthetic testing and identification. Emphasis is on design of geosynthetic earth reinforcement, roadway stabilization, filters, and waste containment systems. Prerequisite: Civ Eng 3715 with grade of "C" or better.

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**CIV ENG 5750 Transportation Applications of Geophysics** (LEC 2.0 and LAB 1.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5761 and Geophys 5761).

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**CIV ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CIV ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CIV ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**CIV ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CIV ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CIV ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CIV ENG 6123 Pavement Management, Evaluation and Rehabilitation** (LEC 2.0 and LAB 1.0)

Advanced knowledge of pavement performance; pavement evaluation; implementation of pavement management at network and project levels; maintenance and rehabilitation strategies; life-cycle cost analysis. Prerequisites: Graduate Standing.

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**CIV ENG 6131 Fundamentals of Rheology & Self Consolidating Concrete** (LEC 3.0)

Discuss various rheological testing protocols & models applicable to cement-based materials and present relationships between rheological parameters and workability of grout and concrete. Understand key performance characteristics of specialty concretes, including self-consolidating, underwater, pumped & shotcrete. Prerequisites: Graduate Standing.

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**CIV ENG 6141 Principles of Rheology** (LEC 3.0)

The relation of the flow/deformation behavior of materials (liquids and flowing solids) and their internal structure is studied theoretically. The tools and most common procedures to measure the rheological properties of these materials are introduced and demonstrated. Different applications of rheology are presented and special problems discussed. Prerequisites: Civ Eng 2210 and Civ Eng 3330.

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**CIV ENG 6201 Analysis And Design Of Plates And Shells I** (LEC 3.0)

Fundamental theories of bending and buckling of plates for practical applications in analysis and design of bridge and building floors, highway and airport pavements, and structural plate components. Shell theory with application to tanks, pressure vessels, shell roofs, and folded plate construction. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6205 Structural Dynamics and Earthquake Engineering** (LEC 3.0)

Behavior of structural materials, elements, and systems under earthquake loads; computer methods for response analysis of lumped and distributed mass models, eigensolution techniques, response spectral analysis, design of 2-D and 3-D seismic resistant structures with current design codes. Prerequisite: Civ/Arch Eng 5208 or equivalent.

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**CIV ENG 6206 Stochastic Theory of Structural Dynamics** (LEC 3.0)

Probability theory and application in structural dynamics. Stochastic models for earthquake-induced forces and wind effects on structure. Solutions for linear and nonlinear structures. Reliability-based evaluation of structural performance under random loading. Simulation of stochastic processes. Prerequisites: Math 3304; Mech Eng 5307 or Civ Eng 6205, and Stat 3115.

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**CIV ENG 6207 Finite Element Application in Structural Design** (LEC 3.0)

Concepts of analysis and design. Generalized coordinate models and isoparametric derivations for one, two, and three dimensional elements. Systems with plate and shell elements. Structural instability problems. Elastic and inelastic systems for static and dynamic loads. Studies of computer programs.

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**CIV ENG 6208 Analysis Of Nonlinear Structures** (LEC 3.0)

Inelastic behavior of structural members and connections; formulation of various models for steel and reinforced concrete including elasto-plastic, bilinear, trilinear, Ramberg-Osgood, Cheng-Mertz, and Cheng-Lou; matrix analysis of 2-D and 3-D building structures for geometric and material nonlinearity; dynamic and stability analysis. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6211 Plastic Analysis And Design Of Metal Structures** (LEC 3.0)

Behavior of engineering materials in the inelastic stress range. Analysis and design of elementary structural members and frames.

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**CIV ENG 6213 Advanced Design in Steel and Lightweight Structures** (LEC 3.0)

A critical evaluation of the theories of design and actual behavior of metal components and their connections. The basis of the development of the pertaining codes will be considered. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6221 Advanced Behavior Of Reinforced And Prestressed Concrete** (LEC 3.0)

Behavior of reinforced and prestressed concrete sections, members and wall/shell-type elements subjected to bending, axial load, shear and torsion. Confinement of concrete. Various truss model theories applicable to main members and strut-tie model applicable to disturbed regions, joints, and connections. Prerequisite: Civ Eng 3220 with grade of "C" or better.

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**CIV ENG 6331 Advanced Hydraulics And Hydraulic Engineering** (LEC 3.0)

Studies in the field of hydraulic engineering to fit the needs of a particular student or class. Each student makes a complete design of a hydraulic development in one of the following fields; water power, sanitation, river and harbor projects. Prerequisite: Civ Eng 3330.

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**CIV ENG 6335 Hydraulic Structures** (LEC 3.0)

Gravity, arch, multiple arch, and buttress dams including appurtenances such as spillways, penstocks and gates. Latter part of course is designed to needs of the individual student with applications to river and harbor structures, canal and irrigation structures, and sewage structures. Prerequisites: Civ Eng 3220 and 3330.

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**CIV ENG 6338 Advanced Hydrology** (LEC 3.0)

A study of methods used in modern hydrologic analysis and design. Items of study include hydrography analysis, maximum possible storm, infiltration, design flood determination and project feasibility. Prerequisite: Civ Eng 3333.

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**CIV ENG 6340 Urban Hydrology** (LEC 3.0)

Studies of the influence of urban areas on their hydrology. Special emphasis on the principles of spatially varied unsteady flow. Model hydrographs leading toward determination of design storm flow are utilized to obtain information necessary for design of storm sewers, channels, and hydraulic structures common to urban areas. Prerequisite: Civ Eng 3333.

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**CIV ENG 6442 Construction Administration, Planning and Control** (LEC 3.0)

Study of construction project development and execution, ranging from preliminary engineering to project turnover. Key topics include bidding strategies, quality control, conceptual estimating, scheduling, progress and cost control, value engineering, safety and construction productivity. Prerequisite: Preceded or accompanied by Civ Eng 5445.

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**CIV ENG 6443 Contract Formulation And Project Delivery Systems** (LEC 3.0)

Project life-cycle planning and management. Roles and responsibilities of contract participants. Construction contract formulation. Obtaining work by negotiating and by bidding. Forms and variations of project delivery systems. Prerequisite: Civ Eng 5445 or Civ Eng 5449.

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**CIV ENG 6445 Advanced Construction Engineering** (LEC 3.0)

Study of the temporary structures and plant used in construction. Key topics include legal implications, codes and regulations, falsework, slipforming, bridge construction supports, and protection of adjacent facilities. Prerequisite: Preceded or accompanied by Civ Eng 5445.

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**CIV ENG 6501 Transportation Planning** (LEC 3.0)

Study of urban development, mobility patterns, and the transportation network. Transportation modeling techniques; transportation control plans to improve air quality; consideration of the transportation disadvantaged; transportation planning in smaller cities and rural areas. Access management and site impact analysis of traffic generators. Prerequisite: Civ Eng 5513 or consent of instructor.

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**CIV ENG 6505 Traffic Modeling and Simulation** (LEC 3.0)

Fundamentals of system simulation, components of a simulation model, traffic flow simulation approaches, traffic flow simulation software and their applications, building simulation models, verification and validation of a simulation model, output analysis, variance reduction techniques, role of simulation in Intelligent Transportation Systems (ITS). Prerequisites: Stat 3113, Civ Eng 3500 preceded or accompanied by Civ Eng 5513.

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**CIV ENG 6509 Traffic Flow Theory and Characteristics** (LEC 3.0)

This course will cover advanced theories of traffic flow, traffic flow characteristics, statistical distributions of traffic flow parameters, traffic stream models, car following models, shock wave analysis, queuing analysis, traffic flow models for intersections, traffic simulation. Prerequisites: Preceded or accompanied by Civ Eng 5513, knowledge of statistics, graduate standing or consent of instructor.

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**CIV ENG 6511 Transportation Systems Analysis** (LEC 3.0)

Concepts and principles fundamental to the planning, design, operation, and management of transportation systems using a systems perspective to transportation problems. Concepts from economics, engineering, operations research, management, psychology, and public policy analysis are used throughout. Topics include linear and non-linear programming, dynamic programming, supply-demand microeconomic framework, analysis of transportation demand, system performance, network equilibrium, simulation and associated case studies. Prerequisite: Civ Eng 5513.

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**CIV ENG 6600 Chemical Principles In Environmental Engineering** (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Env Eng 6600).

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**CIV ENG 6601 Biological Principles In Environmental Engineering Systems** (LEC 2.0 and LAB 1.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Env En 6601).

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**CIV ENG 6602 Environmental Chemistry** (LAB 1.0 and LEC 2.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Env En 6602).

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**CIV ENG 6608 Environmental Engineering Analysis Laboratory** (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Env Eng 6608).

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**CIV ENG 6611 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6611 and Chem Eng 6330).

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**CIV ENG 6612 Biological Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion processes. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6612).

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**CIV ENG 6671 Industrial And Hazardous Waste Treatment** (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Env En 6671).

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**CIV ENG 6712 Computer Modeling in Geotechnical Engineering** (LEC 3.0)

Survey of computer methods of analyzing and modeling complex geotechnical engineering problems. Computer applications, data analysis, and result interpretations. Topics include constitutive modeling, foundation engineering, seepage, unsaturated flow problem, slope stability analysis, consolidation, excavation, tunneling, and dynamic soil-structure interaction. Prerequisite: Civ Eng 3715 and graduate standing.

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**CIV ENG 6713 Dynamics of Earth Materials** (LEC 3.0)

Theory of vibration, spectral response, site-specific response spectra, detailed design of retaining structures, pile and machine foundations, soil structure interaction. Dynamic soil properties, including degradation of soil properties and liquefaction, seismic slope stability analysis problem solving. Select research topics and use of computer codes. Prerequisite: Preceded or accompanied by Civ Eng 5715.

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**CIV ENG 6714 Measurement Of Soil Properties** (LEC 2.0 and LAB 1.0)

Laboratory determination of soil properties with emphasis on practical. Applications of test data. Tests include classification, atterberg limits, consolidation, compaction, triaxial shear tests with pore pressure measurement, and direct shear tests. Preparation of technical reports. Prerequisites: CIV ENG 3715.

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**CIV ENG 6715 Advanced Soil Mechanics** (LEC 3.0)

Advanced topics and recent advances in theoretical soil mechanics. Topics may include stress distribution, failure theories, shear failure in ideal soils, consolidation and settlement, physico-chemical properties, and clay mineralogy. Prerequisite: Civ Eng 5715.

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**CIV ENG 6716 Soil Stabilization** (LEC 3.0)

The application of mineralogical and physicochemical principles to soil stabilization problems and stabilization techniques for highway and foundation applications. Prerequisite: Civ Eng 5715.

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**CIV ENG 6717 Earth Dams And Related Problems** (LEC 3.0)

The exploration for and selection of site and materials, seepage analysis, slope stability and design, embankment design, compaction, instrumentation and construction operations as they pertain to earth and rockfill dams. Prerequisite: Civ Eng 5715.

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**CIV ENG 6729 Foundation Engineering III** (LEC 3.0)

A critical study of modern concepts of foundation engineering including current procedure for the application of soil mechanics principles to the design of foundations, embankments and retaining structures. Case histories will be emphasized with the student making successive design decisions.

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**CIV ENG 6760 Inca Civilization Geotechnical Engineering Practices** (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Geo Eng 6407).

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**CIV ENG 6801 Advanced Concrete Science and Technology** (LEC 3.0)

The course covers advanced notions of concrete science and technology. It discusses various aspects related to cement manufacturing, cement hydration and microstructure, use of supplementary cementitious materials and chemical admixtures, rheology and workability, mechanical properties, dimensional stability, durability, and sustainability of concrete. Prerequisites: Civ Eng 5113 or equivalent; or consent of the instructor with Graduate Standing. (Co-listed with Arch Eng 6801).

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**ENV ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department.

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**ENV ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENV ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Comp Eng 5070, Elec Eng 5070, Civ Eng 5070).

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**ENV ENG 5360 Water Resources And Wastewater Engineering** (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Civ Eng 5360).

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**ENV ENG 5605 Environmental Systems Modeling** (LEC 3.0)

Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Civ Eng 5605).

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**ENV ENG 5619 Environmental Engineering Design** (LAB 1.0 and LEC 2.0)

Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Civ Eng 5619).

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**ENV ENG 5630 Remediation of Contaminated Groundwater And Soil** (LEC 2.0 and LAB 1.0)

Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Civ Eng 5630).

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**ENV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design** (LEC 3.0)

Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisite: Env Eng 3615 or Civ Eng 3615 or graduate standing. (Co-list with Civ Eng 5635).

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**ENV ENG 5640 Environmental Law And Regulations** (LEC 3.0)

This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, and CERCLA. Case studies will be emphasized. (Co-listed with Civ Eng 5640).

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**ENV ENG 5642 Sustainability, Population, Energy, Water, and Materials** (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Civ Eng 5642 and Arch Eng 5642).

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**ENV ENG 5650 Public Health Engineering** (LEC 3.0)

A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with grade of "C" or better. (Co-listed with Civ Eng 5650).

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**ENV ENG 5660 Introduction To Air Pollution** (LEC 3.0)

Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5660).

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**ENV ENG 5662 Air Pollution Control Methods** (LEC 3.0)

Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5662).

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**ENV ENG 5665 Indoor Air Pollution** (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Civ Eng 5665 and Arch Eng 5665).

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**ENV ENG 5670 Solid Waste Management** (LEC 3.0)

A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Civ Eng 5670).

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**ENV ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

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**ENV ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENV ENG 6010 Seminar** (IND 0.0)

Discussion of current topics.

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**ENV ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**ENV ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of instructor.

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**ENV ENG 6600 Chemical Principles In Environmental Engineering** (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Civ Eng 6600).

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**ENV ENG 6601 Biological Principles In Environmental Engineering Systems** (LAB 1.0 and LEC 2.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Civ Eng 6601).

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**ENV ENG 6602 Environmental Chemistry** (LEC 2.0 and LAB 1.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Civ Eng 6602).

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**ENV ENG 6608 Environmental Engineering Analysis Laboratory** (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Civ Eng 6608).

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**ENV ENG 6611 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6611 and Chem Eng 6330).

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**ENV ENG 6612 Biological Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion process. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6612).

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**ENV ENG 6671 Industrial And Hazardous Waste Treatment** (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Civ Eng 6671).

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## Computer Engineering

The mission of the computer engineering program, consistent with the Missouri S&T campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society's problems in the area of computer engineering.

The computer engineering program in the department of electrical and computer engineering offers graduate programs of study which lead to the M.S. degree (thesis and non-thesis options) and the Ph.D. degree. Both the Rolla campus and Missouri S&T Global - St. Louis offer M.S. programs. A great variety of multidisciplinary programs and research areas are available. Most graduate programs in computer engineering normally include some specialization in one or more of the following:

### Emphasis Areas

- **Integrated circuits and logic design:** Topics include hardware/software co-design, IC design, electromagnetic compatibility, VLSI design, and secure embedded systems design.
- **Networking, security and dependability:** Topics include network analysis and synthesis, cyber-physical systems, wireless networks, sensor networks, dependability, and fault tolerance.
- **Computer architecture and embedded systems:** Topics include high performance systems, parallel processors, GPU computing, and heterogeneous systems architecture.
- **Computational intelligence:** Topics include clustering, adaptive resonance and reinforcement learning architectures, learning and adaptation, hardware and applications, neurofuzzy regression, traveling salesman problem heuristics, robotic swarms, bioinformatics, medical informatics, machine vision, and automation.

### Departmental Requirements

The nominal GPA requirement for admission to the M.S. degree program in this department is an undergraduate GPA of 3.3 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example, we cannot accept students who have only a diploma or engineering technology degree.

The ECE department requires ETS reported GRE scores and recommends the following:

ETS scoring:  $Q+V=305$ ,  $Q \geq 160$ ,  $A/WR \geq 3.5$

This GRE requirement may be waived if the applicant has an undergraduate GPA of 3.5 obtained from the courses offered by the electrical engineering or computer engineering program at Missouri S&T (must be minimum 18 credit hours).

For international students who are required to provide TOEFL scores, the ECE department has no preference as to the computer based TOEFL (CBT), internet based TOEFL (iBT), or paper based TOEFL (PBT). Recommended scores set by the department are 230 CBT, 88 iBT, and 570 PBT. Where TOEFL is not available, IELTS score of  $\geq 6.5$  is strictly required.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed

on their admission. These conditions are generally imposed to make sure that students lacking a traditional Computer Engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the Ph.D. program should meet or exceed all of the above recommendations and should have a graduate GPA of 3.5 or better. All Ph.D. applicants must provide at least three letters of recommendation. Exceptional applicants may apply directly to the Ph.D. program after completing the baccalaureate degree.

### M.S. Degree Requirements

Thesis option M.S. programs of study require a minimum of 21 credit hours of coursework exclusive of credit hours earned for thesis research. The thesis option degree is based on a combination of coursework and research. This option requires the student to find a faculty member willing to serve as advisor. This should be done as soon as possible so that the student and advisor will be able to formulate both a plan of coursework and a research project.

Non-thesis option M.S. program is based entirely on coursework. This option requires a minimum of 30 credit hours of coursework. Non-thesis students are assigned an initial advisor by the department, typically the associate chair for graduate studies. M.S. degree students, both thesis and non-thesis option, may change this degree option and advisors at any time with the consent of their current and new advisors.

#### M.S. Communication Requirements

A M.S. student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

### Ph.D. Degree Requirements

The two types of doctoral degrees offered by this department are the Doctor of Philosophy (Ph.D.) and the Doctor of Engineering (D.E.) with a strong emphasis on research with advisor. The primary difference between these two doctoral degrees is that the research portion of the D.E. degree is conducted as an internship with an industrial concern or government laboratory and is jointly supervised by an internship advisor employed by the cooperating organization and a faculty advisor employed by S&T. In contrast, the research portion of the Ph.D. degree is generally conducted on campus.

The doctoral program of study, for the Ph.D. degree or the D.E. degree, should include 90 credit hours (minimum 48 hours coursework and minimum 42 hours research) beyond the B.S. degree or 60 credit hours (minimum 24 hours coursework and minimum 36 hours research) beyond the M.S. degree.

### Ph.D Communication Requirement

A doctoral student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

## Research

Significant research, suitable for publication, is expected for students pursuing the thesis option M.S. or a doctoral degree. The student should work closely with their major advisor and their advisory committee to determine when these expectations are met. The length of research time and/or the number credit hours earned for thesis research will not automatically satisfy this requirement.

## Additional Information

Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the department's web page at <http://ece.mst.edu>. We can be contacted by telephone at 573-341-4519 or email at [ecegrad@mst.edu](mailto:ecegrad@mst.edu). For information about the Engineering Education Center in St. Louis, visit their web page at <http://eec.mst.edu>.

## Graduate Certificate Programs

(Also offered in the systems engineering or computer science disciplines)

There are three graduate certificate programs that utilize computer engineering graduate level courses to develop the skills of practicing engineers, including cyber physical systems, information assurance and security officer essentials, and computational intelligence. Details for these programs can be obtained from <http://dce.mst.edu/credit/certificates/>. The four courses taken to fulfill the requirements of any of the graduate certificate programs can, under certain circumstances, be counted towards an M.S. degree. However, any prerequisite or remedial courses taken to provide background for one or more of the four graduate certificate program courses cannot be counted towards an M.S. degree.

In order for a required graduate certificate course in cyber physical systems to count for graduate credit the graduate certificate program must have been successfully completed, as described in the Admission and Program Procedures section, and the applicant must apply for and be accepted into the graduate program (computer engineering, computer science, or systems engineering) specified at the time the applicant was accepted into the specific graduate certificate program.

These programs are designed to appeal to working professionals.

### Computational Intelligence Certificate

Recent advances in information technology and the increased level of interconnectivity that society has achieved through Internet and broadband communication technology created systems that are very

much different. The world is facing an increasing level of systems integration leading towards systems of systems (SoS) that adapt to changing environmental conditions. The number of connections between components, the diversity of the components and the way the components are organized can lead to different emergent system behavior. Computational Intelligence tools are an integral part of these systems in enabling adaptive capability in their design and operation.

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use and development of computational intelligence algorithms based on evolutionary computation, neural networks, fuzzy logic, and complex systems theory. Engineers can also learn how to integrate common sense reasoning with computational intelligence elective courses such as data mining and knowledge discovery.

#### Core Courses

COMP ENG 5310/ ELEC ENG 5310/ SYS ENG 5211	Computational Intelligence	3
Select one of the following:		
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications	3
COMP SCI 5400	Introduction To Artificial Intelligence	3
COMP SCI 5401	Evolutionary Computing	3
Select two of the following not taken as a core course:		
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications	3
ELEC ENG 5320	Neural Networks Control and Applications	3
COMP SCI 5400	Introduction To Artificial Intelligence	3
COMP SCI 5401	Evolutionary Computing	3
COMP SCI 6400	Advanced Topics In Artificial Intelligence	3
COMP SCI 6401	Advanced Evolutionary Computing	3
SYS ENG 6213	Deep Learning and Advanced Neural Networks	3
SYS ENG 6214/ COMP ENG 6330/ ELEC ENG 6340/ STAT 6239	Clustering Algorithms	3
SYS ENG 6215/ COMP ENG 6320/ ELEC ENG 6360	Adaptive Dynamic Programming	3
SYS ENG 6216/ COMP ENG 6302/ COMP SCI 6402	Advanced Topics in Data Mining	3
COMP ENG 6310/ ENG MGT 6410/ COMP SCI 6202/ MECH ENG 6447/ AERO ENG 6447	Markov Decision Processes	3

### Cyber Physical Systems Graduate Certificate

Cyber Physical Systems with different levels of implementation that entail complex logic with many levels of reasoning in intricate arrangement, organized by web of connections and demonstrating self-driven adaptability are emerging. They will impact manufacturing industry, defense, healthcare, energy, transportation, emergency response, agriculture and society overall. The graduate certificate in Cyber Physical systems is a joint effort between computer engineering and systems engineering to provide practicing engineers with the necessary skills to develop and design the operation of complex adaptive systems. These four courses count towards a M.S. degree in systems engineering or computer engineering and they address the intersection between computer engineering engineering, systems engineering, and architecting. The requirements are the successful completion of two core courses and two elective courses from the list below. A grade of "B"

or better is required in each course before the student is eligible for the master of science program.

Core Course:

SYS ENG 6321/ COMP ENG 6410	Modeling Complex Systems	3
COMP ENG 5410	Introduction to Computer Communication Networks	3
Elective Courses (Select two courses):		
COMP ENG 5420	Introduction to Network Security	3
COMP ENG 5430/ SYS ENG 5323	Wireless Networks	3
COMP ENG 5510	Fault-Tolerant Digital Systems	3
SYS ENG 6322/ COMP ENG 6510	Resilient Networks	3
COMP ENG 6420/ SYS ENG 6324	Wireless Ad hoc and Sensor Networks	3
COMP ENG 6430	High Speed Networks	3
COMP ENG 6440/ COMP SCI 6602	Network Performance Analysis	3
COMP SCI 6600	Formal Methods in Computer Security	3
COMP SCI 6604	Mobile And Sensor Data Management	3

**Levent Acar**, Associate Professor

PHD Ohio State University

Control and systems, intelligent control with applications to robotics, neural network and fuzzy logic systems, large-scale systems and optimization.

**Ahmad Alsharwa**, Assistant Professor

PHD Iowa State University

**Daryl G Beetner**<sup>1</sup>, Professor

DSC Washington University

Electromagnetic immunity and emissions at the chip and system level detection, detection and neutralization of explosive devices, skin cancer detection.

**Rui Bo**, Assistant Professor

PHD Univeristy of Tennessee-Knoxville

Computation, optimization and economics in power system operation and planning, high performance computing and its application in power systems, electricity market simulation, evaluation and design.

**Minsu Choi**, Associate Professor

PHD Oklahoma State University

Computer architecture and VLSI, embedded systems, fault tolerance testing, quality assurance, reliability modeling and analysis, configurable computing, distributed systems and dependable instrumentation and measurement.

**Kristen Marie Donnell Hilgedick**, Associate Professor

PHD Missouri Univeristy of Science & Technology

Microwave nondestructive testing, modulated antennas/scatterers and terahertz methodologies and electronics design.

**Kelvin Todd Erickson**<sup>1</sup>, Professor

PHD Iowa State University

Chemical process control, advanced control algorithms, digital control, programmable logic controllers, and systems identification.

**Mina Esmaelpour**, Assistant Professor

PHD Lehigh University

**Jun Fan**, Professor

PHD University of Missouri-Rolla

Intra-system electromagnetic compatibility, Radio-Frequency interference, signal/power integrity and high-speed printed circuit boards and packages.

**Mehdi Ferdowsi**, Professor

PHD Illinois Institute of Technology

Power electronics, power converters and electric drives.

**Jie Huang**, Assistant Professor

PHD Clemson University

Fiber optic sensors, laser machining, sensors and instrumentation for applications in harsh environments, microwave-photonic sensing imaging and spectroscopy.

**Ali Hurson**, Professor

PHD University of Central Florida

Parallel and distributed systems, databases, mobile-databases, pervasive and mobile computing.

**Chulsoon Hwang**, Assistant Professor

PHD KAIST, Daejeon, Korea

Signal and power integrity of IC/package/PCB system, electromagnetic modeling, time/frequency domain simulation/measurement techniques.

**Chang-Soo Kim**, Professor

PHD Kyungpook National University

Micro-and nano-sensors, bio-MEMS (Micro Electro Mechanical System), microsystems, sensor engineering, biomedical/agricultural engineering.

**DongHyun Kim**, Assistant Professor

PHD Kaist, Korea

**Jonathan William Kimball**<sup>1</sup>, Professor

PHD University of Illinois-Urbana

Power electronics, energy harvesting, alternative energy, and multi-phase converters.

**Kurt Louis Kosbar**, Associate Professor

PHD University of Southern California

Statistical communication theory, spread spectrum systems, computer aided design of communication systems, stochastic process theory, and digital signal processing.

**Jagannathan Sarangapani**, Professor

PHD University of Texas-Arlington

Control of networks, embedded systems, MEMS, intelligent systems/control, diagnostics/prognostics, and biomedical applications.

**Sahra Sedighsarvestani**, Associate Professor

PHD Purdue University-W. Lafayette

Component-based software engineering and enterprise integration.

**Pourya Shamsi**, Associate Professor

PHD University of Texas-Dallas

Smart-grids, stability assessments in micro-grids, energy management, switching power converters, VHF/UHF dc-dc converters, and motor drives.

**Ronald Joe Stanley**, Professor

PHD University of Missouri-Columbia

Image and signal processing, computational intelligence, automation and medical informatics.

**Steve E Watkins**, Professor  
PHD University of Texas at Austin  
Fiber optic sensing, optical and electronic materials, electro-optic devices and engineering education.

**Cheng Hsiao Wu**, Professor  
PHD University of Rochester  
Quantum resistor network theory, semiconductor device modeling, DLTS measurement, and optical computing.

**Donald C Wunsch II**, Professor<sup>1</sup>  
PHD University of Washington  
Adaptive critic designs, neural networks, fuzzy systems, surety, nonlinear adaptive control, intelligent agents, applications and financial engineering.

**Maciej J Zawodniok**, Associate Professor  
PHD University of Missouri-Rolla  
Embedded systems for cyber infrastructure, wireless sensor and ad hoc networks, and general wireless communications systems.

**Jiangfan Zhang**, Assistant Professor  
PHD Lehigh University  
Statistical signal processing for cyber-physical systems, Internet of Things, sensor networks, cybersecurity, smart grid, radar and sonar processing.

**COMP ENG 5000 Special Problems** (IND 1.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**COMP ENG 5001 Special Topics** (LEC 1.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**COMP ENG 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**COMP ENG 5070 Teaching Engineering** (LEC 3.0)  
Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Elec Eng 5070, Civ Eng 5070).

**COMP ENG 5099 Special Research And Thesis** (IND 1.0-15)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

**COMP ENG 5110 Principles of Computer Architecture** (LEC 3.0)  
Principles of performance measurement and instruction set design; advanced issues in pipelining; instruction level parallelism (dynamic scheduling, branch prediction, multi-issue processors); memory hierarchies for superscalar processors; multiprocessors; multi-threading; storage systems; and interconnection networks. Prerequisite: Comp Eng 3110. (Co-listed with Comp Sci 5803).

**COMP ENG 5120 Digital Computer Design** (LEC 3.0)  
Organization of modern digital computers; design of processors, memory systems and I/O units, hardware-software tradeoffs in different levels of computer system design. Prerequisites: COMP ENG 3150 and COMP ENG 3151.

**COMP ENG 5130 Advanced Microcomputer System Design** (LEC 3.0)  
The design of digital systems based on advanced microprocessors. Introduction to microcomputer logic development systems. I/O interfaces. Assembly and high level language tradeoffs. Hardware and software laboratory projects required. Prerequisites: COMP ENG 5110.

**COMP ENG 5151 Digital Systems Design Laboratory** (LEC 2.0 and LAB 1.0)  
Design of 32-bit microcontroller based systems. Topics include the instruction set architecture of a 32-bit microcontroller, assembly language and C programming, using microcontroller peripherals for communication, measurement and control. Student designs, programs and tests microcontroller based projects. Prerequisites: Comp Eng 3150 or Comp Eng 5110.

**COMP ENG 5160 Embedded Processor System Design** (LEC 3.0)  
Development of hardware and software for embedded systems, including real-time operating systems, advanced programming, communication schemes, hardware peripherals and sensors, control methodologies, printed-circuit board design, interrupts, microcontrollers, and hardware-software co-design. One or more team design projects. Prerequisites: COMP ENG 3150 or equivalent or 80x51 processor experience.

**COMP ENG 5170 Real-Time Systems** (LEC 3.0)  
Introduction to real-time (R-T) systems and R-T kernels, also known as R-T operating systems, with an emphasis on scheduling algorithms. The course also includes specification, analysis, design and validation techniques for R-T systems. Course includes a team project to design an appropriate R-T operating system. Prerequisites: COMP ENG 3150 or COMP SCI 3800. (Co-listed with Comp Sci 5205).

**COMP ENG 5210 Introduction To VLSI Design** (LEC 3.0)  
An introduction to the design and analysis of digital integrated circuits (ICs). Topics include basic manufacturing techniques, transistor-level design and analysis of logic and memory circuits, logic timing, and parasitics. Computer aided design tools are used to develop circuits in the lab. Prerequisites: Elec Eng 2200 and Comp Eng 2210.

**COMP ENG 5220 Digital System Modeling** (LEC 3.0)  
Digital system modeling for simulation, synthesis, and rapid system prototyping. Structural and behavioral models, concurrent and sequential language elements, resolved signals, generics, configuration, test benches, processes and case studies. Prerequisite: Comp Eng 2210 with a grade of "C" or better.

**COMP ENG 5230 Optical Computing** (LEC 3.0)

Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisite: Comp Eng 2210 or equivalent. (Co-listed with Elec Eng 5250).

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**COMP ENG 5310 Computational Intelligence** (LEC 3.0)

Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Elec Eng 5810 and Sys Eng 5211).

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**COMP ENG 5410 Introduction to Computer Communication Networks** (LEC 3.0)

Design of computer networks with emphasis on network architecture, protocols and standards, performance considerations, and network technologies. Topics include: LAN, MAN, WAN, congestion/flow/error control, routing, addressing, broadcasting, multicasting, switching, and internetworking. A modeling tool is used for network design and simulation. Prerequisites: Comp Eng 3150 or computer hardware competency and Stat 3117 or Stat 3115 or Stat 5643 or equivalent.

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**COMP ENG 5420 Introduction to Network Security** (LEC 3.0)

This course examines basic issues in network management, testing, and security; it also discusses key encryption, key management, authentication, intrusion detection, malicious attack, and insider threats. Security of electronic mail and electronic commerce systems is also presented. Prerequisite: Comp Eng 5410 or Comp Sci 5600.

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**COMP ENG 5430 Wireless Networks** (LEC 2.0 and LAB 1.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Elec Eng 5430 and Sys Eng 5323).

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**COMP ENG 5450 Digital Image Processing** (LEC 3.0)

Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5450).

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**COMP ENG 5460 Machine Vision** (LEC 3.0)

Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5460).

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**COMP ENG 5510 Fault-Tolerant Digital Systems** (LEC 3.0)

Design and analysis of fault-tolerant digital systems. Fault models, hardware redundancy, information redundancy, evaluation techniques, system design procedures. Prerequisites: Comp Eng 2210 and Comp Eng 2211.

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**COMP ENG 5610 Real-Time Digital Signal Processing** (LEC 2.0 and LAB 1.0)

Introduction to the use of programmable DSP chips. Includes real-time data acquisition, signal generation, interrupt-driven programs, high-level language, and assembly level routines. Applications to real-time systems are also presented. Prerequisite: Elec Eng 3400 or Elec Eng 3410.

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**COMP ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design** (LEC 3.0)

Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Elec Eng 5620).

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**COMP ENG 5803 Mathematical Logic I** (LEC 3.0)

A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Comp Sci 5203, Philos 4354 and Math 5154).

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**COMP ENG 5820 Mechatronics** (LAB 1.0 and LEC 2.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Elec Eng 5870).

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**COMP ENG 5880 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Elec Eng 5880).

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**COMP ENG 6000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department. Prerequisite: Consent of the instructor.

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**COMP ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title. Prerequisite: Consent of the instructor.

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**COMP ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except for the dissertation, and are away from the campus, must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**COMP ENG 6099 Special Research and Thesis** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

**COMP ENG 6110 Advanced Computer Architecture I** (LEC 3.0)

Advanced topics in computer structures, parallel processors, and computer networks. Emphasis on their design, applications, and performance. Prerequisite: Comp Eng 5110 or Comp Eng 5120. (Co-listed with Comp Sci 6801).

**COMP ENG 6120 Advanced Computer Architecture II** (LEC 3.0)

Continuation of Computer Engineering 6110. Prerequisites: COMP ENG 6110.

**COMP ENG 6210 Digital Logic** (LEC 3.0)

Digital logic analysis, synthesis and simulation. Design automation of digital systems. Prerequisites: Comp Eng 2210 and Comp Eng 2211.

**COMP ENG 6230 Advanced VLSI Design** (LEC 3.0)

Advanced topics in chip-level VLSI design, including issues related to high-performance, low-power, analog and mixed-signal circuits, reliability, noise and coupling mechanisms, computer aided design tools, and recent advances and trends in the field. Prerequisite: Comp Eng 5210 is required.

**COMP ENG 6302 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 301 Introduction to Data Mining. (Co-listed with Comp Sci 6402 and Sys Eng 6216).

**COMP ENG 6310 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Mech Eng 6447, Aero Eng 6447, Eng Mgt 6410, Comp Sci 6202 and Sys Eng 6217).

**COMP ENG 6320 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Elec Eng 6360, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

**COMP ENG 6330 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Elec Eng 6830, Sys Eng 6214, Comp Sci 6405, Stat 6239).

**COMP ENG 6410 Modeling Complex Systems** (LEC 3.0)

Engineering Systems of today are non-linear, distributed, global, and adaptive to their environment in both space and time, thereby creating emergent behaviors. This course covers the current modeling tools and techniques used in modeling and architecting these complex systems. Prerequisites: Graduate Standing. (Co-listed with SYS ENG 6321).

**COMP ENG 6420 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Elec Eng 6430 and Sys Eng 6324).

**COMP ENG 6430 High Speed Networks** (LAB 1.0 and LEC 2.0)

A state-of-the-art survey of high-speed networks, modeling and simulation, quality of service (QoS) for multimedia applications and management schemes, TCP congestion control, ATM and Internet traffic management, Internet Service Architecture (ISA), and Internet routing protocols. Prerequisites: Comp Eng 5410 and hardware competency for ECE students, Comp Sci 4600 for computer science students, or consent of the instructor.

**COMP ENG 6440 Network Performance Analysis** (LEC 3.0)

Provides an introduction to performance modeling and analysis of computer networks. Topics include stochastic processes; performance measurement and monitoring; quantitative models for network performance, e.g., Markovian models for queues; simulation; and statistical analysis of experiments. Prerequisites: Comp Eng 5410 or Comp Sci 4600; Stat 3117 or 5643. (Co-listed with Comp Sci 6602).

**COMP ENG 6510 Resilient Networks** (LEC 3.0)

This course presents reliability and fault tolerance for network-centric systems, including models, metrics, and analysis techniques. This course also concentrates on security, including technical tools and methods for audit and assessment as well as management and policy issues. Prerequisites: Sys Eng 6410, Comp Eng 6410, or Comp Eng 5420. (Co-listed with SYS ENG 6322).

## Computer Science

The computer science department offers comprehensive M.S. and Ph.D. degree programs that focus on computer network security, software engineering, web databases, wireless systems, intelligent systems, data mining, parallel and distributed processing pervasive computing, computer networks, scientific visualization, and algorithms.



These research activities support the department's two major areas of excellence: software engineering and critical infrastructure protection.

The computer science department at Missouri S&T makes use of both its own computer learning center (CLC) as well as university CLCs. The CLC contains a mix of Linux and Windows computing platform. Class sizes are kept small to facilitate student and faculty interactions. Research laboratories provide support for both undergraduate and graduate students. These laboratories include:

- Advanced Networking and Cyber-Physical Systems Laboratory
- Applied Computational Intelligence Laboratory
- CRWMan Laboratory
- Critical Infrastructure Protection Laboratory
- Cybersecurity Laboratory
- Data Mining Laboratory
- Pervasive and Mobile Computing Laboratory
- Web and Wireless Computing (W2C) Laboratory & Net-Centric Center

Wired and wireless computer access is available to all students, faculty, and staff.

## Financial Assistance

Financial assistance is available to graduate students in the form of research assistantships, teaching assistantships, and fellowships. Applications for computer science assistantships can be found on the department's web page or by contacting the department directly (see below). In addition, research opportunities for advanced students exist in the department and in the Missouri S&T Intelligent Systems Center as well as other research labs on campus.

## Additional Information

Additional information about department emphasis areas, requirements, faculty, labs, and research opportunities can be found at <http://cs.mst.edu> or email [csgadcoord@mst.edu](mailto:csgadcoord@mst.edu) or phone at 573-341-6642. More information about distance education can be obtained from <http://dce.mst.edu>.

## Admissions Requirements

In addition to those requirements stated in the section of this catalog devoted to Admission and Program Procedures, the computer science department has additional requirements for each of its degree areas.

### M.S. in Computer Science (thesis or non-thesis)

A minimum GRE verbal score of 370/144 and for those whom English is not their native language, a TOEFL score of 570/230/89. Minimum GRE Quantitative Score  $\geq$  700/155. Written score  $\geq$  4.0.

An undergraduate GPA of 3.0/4.0 or better over the last 2 years or successful completion of 12 graduate hours in computer science as a "conditional" graduate student at Missouri S&T, with at least a 3.0 GPA, as per graduate requirements.

Applicants are expected to have strong mathematical skills, competency in a modern programming language, and knowledge of the following computer science core subjects:

- Algorithms and Data Structures
- Computer Organization/Architecture
- Database and File Structures
- Discrete Mathematics
- Operating Systems

The department offers a distance M.S. degree program via the Internet. (Admissions and degree requirements are the same as the regular M.S. program.)

## M.S. in Computer Science

Application is made to the Missouri S&T admissions office along with the required transcripts, statement of purpose and GRE verbal, quantitative, and analytical test scores.

The M.S. in computer science (thesis and non-thesis) is a 31 credit hour program. M.S. students are required to take and pass the graduate seminar course COMP SCI 6010.

## Ph.D. in Computer Science

Application is made to the Missouri S&T admissions office along with the required transcripts and letters of recommendation. Applicants who do not have a graduate degree will normally request admission to the M.S. program first but, outstanding applications will be admitted directly into the Ph.D. program. Applicants must submit a letter outlining tentative research interests and career goals along with GRE verbal, quantitative, and analytical test scores.

Requirements for the Ph.D. in computer science include: Qualifier examination, comprehensive examination, dissertation and defense. The qualifier examination consists of two parts: (i) pass five selected CS graduate level lecture courses and meet the GPA requirements; (ii) conduct a literature study and pass both a written exam and an oral exam. The dissertation should report the results of original research that meets the standards of current disciplinary journal-quality research publications. In addition, Ph.D. students are required to take and pass the graduate seminar course COMP SCI 6010 for three semesters in their Ph.D. studies.

The Ph.D. program is under the guidance of an advisory committee which is appointed no later than the semester following passage of the qualifying exam.

## Graduate Certificates via Distance Education

Graduate certificate programs give students the opportunity to increase their knowledge in specific areas of interest. These courses provide students with the latest knowledge and skills in strategic areas of computing and are presented by Missouri S&T faculty members who are experts in their fields. Most of the courses will be offered through distance education over the internet. Distance education courses use streaming internet video for course delivery. In this setting, students actively participate in classes through viewing the class on their computer while being interactively connected with the class by telephone. Lectures are archived so they may be reviewed at any time during the semester. Instructors are available outside of class time by e-mail and telephone. Where there is sufficient interest, some courses may be taught by traditional instruction methods at Missouri S&T and at off site locations such as Ft. Leonard Wood, St. Louis, and Springfield, MO.

## Big Data Management & Analytics

As the size and availability of datasets increase, so too do the challenges in efficiently and effectively sharing, analyzing, and visualizing information. Proficiency in big data analytics requires knowledge in interdisciplinary areas including computer science, business information technology, mathematics and statistics, and electrical and computer engineering. Currently many colleges and universities worldwide are establishing programs in big data analytics. Missouri S&T faculty have the expertise to provide a unique specialized graduate certificate program to teach practicing computing professionals and graduate students the skills that are necessary for the use and development of big data management, big data analytics, data mining, cloud computing, and business intelligence.

## Big Data Management & Security

Significant data growth leads to challenges in efficiently and securely sharing, accessing, and analyzing big data. Proficiency in big data management and security requires knowledge in interdisciplinary areas including computer science, business information technology, mathematics and statistics, and electrical and computer engineering. Currently many colleges and universities worldwide are establishing programs in big data analytics. Missouri S&T faculty have the expertise to provide a unique specialized graduate certificate program to teach practicing computing professionals and graduate students the skills that are necessary for the use and development of big data securely and efficiently.

## Computational Intelligence Certificate

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use and development of computational intelligence algorithms based on evolutionary computation, neural networks, fuzzy logic, and complex systems theory. Engineers can also learn how to integrate common sense reasoning with computational intelligence elective courses such as data mining and knowledge discovery.

Cyber Security

## Information Assurance and Security Officer Essentials

Protecting information systems is key to protecting the nation's critical infrastructures. Only through diligence and a well-trained workforce will we be able to adequately defend the nation's vital information resources. Missouri S&T's certificate is Certified by the National Security Agency (NSA) Committee on National Security Systems (CNSS) for National Standards 4011 (National Training Standard for Information Systems Security (INFOSEC) Professionals) and 4014E (Information Assurance Training Standard for Information Systems Security Officers (ISSO)).

## Information Systems and Cloud Computing Certificate

The information systems and cloud computing certificate is tailored to the working professional who wants to expand their knowledge of advanced data management technologies. Data mining and knowledge discovery, heterogeneous and mobile databases and cloud computing form the core of the study.

## Software Design and Development Certificate

The software design and development certificate provides an attractive option for the working professional to expand their experience in software engineering. The core of four classes gives a treatment of software project management in its many roles, from overall project management and process improvement to the management of individual

life-cycle components, including software deployment and evolution. Specialized coursework gives depth in advanced object-oriented design, requirements, software quality, testing theory and practice, and an advanced treatment of software metrics.

## Systems and Software Architecture Certificate

The systems and software architect fills a critical role in today's development process, transforming market inputs into the requirements and architecture specification of a product that independent (often remote) development teams can implement. Requests from industrial partners have led to a focused graduate certificate training program.

## Wireless Networks and Mobile Systems Certificate

The wireless networks and mobile systems certificate is designed to provide students an intensive treatment in wireless systems and applications. Coverage includes network architecture and protocols, security and privacy wireless network provisioning and deployment, location and mobility management applications, heterogeneous and mobile databases, and pervasive computing.

**Nan Cen**, Assistant Professor  
PHD Northeastern University

Visible-Light Networking, Internet-of-Things, 5G New Radio, Broadband Wireless Networking, Wireless Multimedia Networks, Optimization, Protocol Design and AI for Wireless Networks.

**Sajal K Das**, St. Clair Endowed Chair Professor  
PHD University of Central Florida

Wireless and sensor networks; mobile and pervasive computing; cyber-physical systems and smart environments; smart healthcare and smart grid; big data; parallel, distributed and cloud computing; security and privacy; systems biology; social networks and social computing; applied graph theory and game theory.

**Yanjie Fu**, Adjunct Professor  
DBA Rutgers University

Data mining and big data analytics, with application to urban computing, mobile analytics, recommender systems, online markets.

**Mike Gosnell**, Assistant Teaching Professor  
MS University of Missouri-Rolla

Programming fundamentals and software engineering, operating systems, discrete mathematics for computer science, relational database systems, parallel, distributed, and grid computing.

**Gerry Howser**, Associate Teaching Professor  
PHD Missouri University of Science and Technology  
Cyber-Physical Systems Security, Mathematical Security Models, and Mathematical Methods in Computing.

**Jennifer Leopold**, Associate Professor  
PHD University of Kansas

Qualitative spatial reasoning, programming languages, scientific visualization, ontologies, database accessibility and analysis.

**Tony Luo**, Associate Professor  
PHD National University of Singapore

Internet of Things, Machine Learning, Security, Trust, and Privacy.

**Sanjay Kumar Madria**, Professor  
PHD Indian Institute of Technology, India

Cloud computing security, wireless computing and mobile data management.

**George Markowsky**, Department Chair  
PHD Harvard University  
CyberSecurity

**Bruce M McMillin**, Professor  
PHD Michigan State University  
Cyber-physical security, distributed systems, formal methods in software engineering.

**Venkata Sriram Siddharth Nadendla**, Assistant Professor  
PHD Syracuse University  
Cyber-Physical-Human Systems; Statistical Inference & Machine Learning; Nudge & Persuasion; Security, Fairness, Transparency and Trust.

**Clayton E Price**, Associate Teaching Professor; Freshman/Transfer Advisor  
MASTER University of Missouri - Rolla  
Introduction to computer science, introduction to programming with C++, C++ programming lab, data structures I, introduction to numerical analysis, object oriented numerical modeling I.

**Chaman L Sabharwal**, Professor  
PHD University of Illinois-Urbana  
Spatial reasoning, graphics, robotics, vision and parallel algorithms.

**Jagannathan Sarangapani**, Professor  
PHD University of Texas-Arlington  
Rutledge Emerson Endowed Chair Professor in Electrical Engineering. Systems and control, cyber physical systems and security, wireless/sensor networks, robotics/autonomous systems, and prognostics.

**Sahra Sedighsarvestani**, Associate Professor  
PHD Purdue University-W. Lafayette  
Embedded systems, environmental and structural monitoring, wireless sensor networks, dependability of critical infrastructures, system and information quality assurance.

**Daniel R. Tauritz**, Adjunct Professor  
PHD Leiden University  
Evolutionary computing, automated design of algorithms, cyber security, and hyper-heuristics.

**Patrick Taylor**, Assistant Teaching Professor  
PHD  
Data structures, introduction to computer security, introduction to programming, bioinformatics.

**Donald C Wunsch II**, Professor<sup>1</sup>  
PHD University of Washington  
Mary K. Finley Missouri Distinguished Professor of Computer Engineering. Clustering, neural networks reinforcement learning, approximate dynamic programming, adaptive dynamic programming, adaptive critic designs, adaptive resonance theory, fuzzy systems, evolutionary computation, particle swarm optimization, nonlinear regression, memristors, game of go (Baduk, Weichi), traveling salesman problem, prisoner's dilemma problem, robotic swarms, bioinformatics, self-healing critical infrastructure, smart grid, critical infrastructure and cybersecurity.

**San Yeung**, Assistant Teaching Professor  
MS Missouri University of Science and Technology  
File Structures, Introduction to Database Systems, and Introduction to Operating Systems.

**Zhaozheng Yin**, Adjunct Professor  
PHD Pennsylvania State University  
Computer vision, biomedical imaging, machine learning, signal processing, and robotics.

**Peizhen Zhu**, Assistant Teaching Professor  
PHD University of Colorado-Denver  
Introduction to MATLAB programming, discrete mathematics for computer science, introduction to numerical methods and algorithms.

**COMP SCI 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**COMP SCI 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**COMP SCI 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP SCI 5099 Research** (IND 0.0-16)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**COMP SCI 5100 Agile Software Development** (LEC 3.0)  
Understand principles of agile software development and contrast them with prescriptive processes. Specifically: Eliciting, organizing, and prioritizing requirements; Design processes; Understand how a particular process promotes quality; Estimate costs and measure project progress and productivity. Prerequisite: A "C" or better grade in Comp Sci 3100.

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**COMP SCI 5101 Software Testing And Quality Assurance** (LEC 3.0)  
It covers unit testing, subsystem testing, system testing, object-oriented testing, testing specification, test case management, software quality factors and criteria, software quality requirement analysis and specification, software process improvement, and software total quality management. Prerequisite: A "C" or better grade in Comp Sci 2500.

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**COMP SCI 5102 Object-Oriented Analysis And Design** (LEC 3.0)  
This course will explore principles, mechanisms, and methodologies in object-oriented analysis and design. An object-oriented programming language will be used as the vehicle for the exploration. Prerequisite: A "C" or better grade in Comp Sci 2500.

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**COMP SCI 5200 Analysis Of Algorithms** (LEC 3.0)  
The purpose of this course is to teach the techniques needed to analyze algorithms. The focus of the presentation is on the practical application of these techniques to such as sorting, backtracking, and graph algorithms. Prerequisite: A "C" or better grade in Comp Sci 2500.

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**COMP SCI 5201 Object-Oriented Numerical Modeling I** (LEC 3.0)

A study of object-oriented modeling of the scientific domain. Techniques and methodologies will be developed enabling the student to build a class library of reusable software appropriate for scientific application. Applications will be drawn from mechanics, finance, and engineering. Prerequisites: A grade of "C" or better in both Comp Sci 3200 and Comp Sci 1575; a grade of "C" or better in one of Math 3108, 3103, 3329.

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**COMP SCI 5202 Object-Oriented Numerical Modeling II** (LEC 3.0)

A continued study of object-oriented modeling of the scientific domain. Advanced applications include models posed as balance laws, integral equations, and stochastic simulations. Prerequisite: A "C" or better grade in Comp Sci 5201.

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**COMP SCI 5203 Mathematical Logic I** (LEC 3.0)

A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Math 5154, Philos 4354 and Comp Eng 5803.)

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**COMP SCI 5204 Regression Analysis** (LEC 3.0)

Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 2222 and one of Stat 3111, 3113, 3115, 3117, or 5643. (Co-listed with Stat 5346).

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**COMP SCI 5204H Regression Analysis-H** (LEC 3.0)**COMP SCI 5205 Real-Time Systems** (LEC 3.0)

Introduction to real-time (R-T) systems and R-T kernels, also known as R-T operating systems, with an emphasis on scheduling algorithms. The course also includes specification, analysis, design and validation techniques for R-T systems. Course includes a team project to design an appropriate R-T operating system. Prerequisites: COMP ENG 3150 or COMP SCI 3800. Co-listed with Comp Eng 5170.

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**COMP SCI 5300 Database Systems** (LEC 3.0)

This course introduces the advanced database concepts of normalization and functional dependencies, transaction models, concurrency and locking, timestamping, serializability, recovery techniques, and query planning and optimization. Students will participate in programming projects. Prerequisite: A "C" or better grade in both Comp Sci 1200 and Comp Sci 2300.

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**COMP SCI 5400 Introduction To Artificial Intelligence** (LEC 3.0)

A modern introduction to AI, covering important topics of current interest such as search algorithms, heuristics, game trees, knowledge representation, reasoning, computational intelligence, and machine learning. Students will implement course concepts covering selected AI topics. Prerequisite: A "C" or better grade in Comp Sci 2500.

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**COMP SCI 5401 Evolutionary Computing** (LEC 3.0)

Introduces evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory (e.g., genetic algorithms), capable of solving complex problems for which other techniques fail. Students will implement course concepts, tackling science, engineering and/or business problems. Prerequisite: A "C" or better grade in both Comp Sci 2500 and in a Statistics course.

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**COMP SCI 5402 Introduction to Data Mining** (LEC 3.0)

The key objectives of this course are two-fold: (1) to teach the fundamental concepts of data mining and (2) to provide extensive hands-on experience in applying the concepts to real-world applications. The core topics to be covered in this course include classification, clustering, association analysis, data preprocessing, and outlier/novelty detection. Prerequisites: A grade of "C" or better in all of Comp Sci 2300, Comp Sci 2500, and one of Stat 3113, Stat 3115, Stat 3117 or Stat 5643.

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**COMP SCI 5403 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Eng 5880 and Elec Eng 5880).

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**COMP SCI 5404 Introduction to Computer Vision** (LEC 3.0)

This course introduces foundational theories and analysis methods in computer vision. Topics will include camera model and geometry, description of visual features, shape analysis, stereo reconstruction, motion and video processing, and visual object recognition. Prerequisite: A "C" or better grade in both Math 3108 and Comp Sci 2500.

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**COMP SCI 5405 Java Gui & Visualization** (LEC 3.0)

Fundamentals of Java Swing Foundation Classes, Java System Language Specifics, Graphical User Interfaces, Images, Audio, Animation, Networking, and Threading. Visualization of Algorithms. GUI Elements include Event Driven Programming, Interaction with Mouse and Keyboard, Window Managers, Frames, Panels, Dialog Boxes, Borders. Prerequisite: A "C" or better grade in Comp Sci 2500 or equivalent.

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**COMP SCI 5406 Interactive Computer Graphics** (LEC 3.0)

Applications and functional capabilities of current computer graphics systems. Interactive graphics programming including windowing, clipping, segmentation, mathematical modeling, two and three dimensional transformations, data structures, perspective views, antialiasing and software design. Prerequisite: A "C" or better grade in both Comp Sci 3200 and Comp Sci 2500.

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**COMP SCI 5500 The Structure of a Compiler** (LEC 3.0)

Review of Backus normal form language descriptors and basic parsing concepts. Polish and matrix notation as intermediate forms, and target code representation. Introduction to the basic building blocks of a compiler: syntax scanning, expression translation, symbol table manipulation, code generation, local optimization, and storage allocation. Prerequisite: A "C" or better grade in both Comp Sci 3500 and Comp Sci 2500.

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**COMP SCI 5600 Computer Networks** (LEC 3.0)

This course focuses on the Internet and the general principles of computer networking. It covers the TCP/IP model from the application layer to the link layer in a top-down approach. It also exposes students to multimedia networking, network security, wireless and mobile networks. It is a networking class targeted for entry-level graduate students.

This course has additional requirements beyond CS4600 on network performance modeling and analysis, development and implementation of complex communication protocols. Credit will not be given if previously have taken CS4600 or CpE 4410/5410. Prerequisite: A "C" or better grade in Comp Sci 3800.

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**COMP SCI 5601 Security Operations & Program Management** (LEC 3.0)

An overview of information security operations, access control, risk management, systems and application life cycle management, physical security, business continuity planning, telecommunications security, disaster recovery, software piracy, investigations, ethics and more. There will be extensive reporting, planning and policy writing. Prerequisite: A "C" or better grade in all of: operating systems, computer networking, and a writing emphasized course.

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**COMP SCI 5602 Introduction to Cryptography** (LEC 3.0)

Introduces fundamentals of modern cryptography. Topics include basic number theory, public & private key encryption schemes, cryptographic hash functions, message authentication codes, elliptic curve cryptography, Diffie-Hellman key agreements, digital signatures, PUFs, quantum cryptography, and generation of prime numbers and pseudo-random sequences. Prerequisites: A grade of "C" or better in COMP SCI 5200 or a grade of "B" or better in COMP SCI 2500.

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**COMP SCI 5700 Bioinformatics** (LEC 3.0)

The course will familiarize students with the application of computational methods to biology, as viewed from both perspectives. It will introduce problems in molecular, structural, morphological, and biodiversity informatics, and will discuss principles, algorithms, and software to address them. Prerequisites: A grade of "C" or better in both one of Bio Sci 1113 or Bio Sci 1213 and one of Comp Sci 1570 and Comp Sci 1580 or Comp Sci 1971 and Comp Sci 1981. (Co-listed with Bio Sci 5323).

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**COMP SCI 5800 Distributed Computing** (LEC 3.0)

This is an introduction to the fundamentals of distributed computing. Topics include a review of communication between distributed processes, causality, distributed state maintenance, failure detection, reconfiguration and recovery, distributed mutual exclusion, clock synchronization, and leader election. Students will implement select course concepts. Prerequisites: A grade of "C" or better in both Comp Sci 3800 and Comp Sci 2500.

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**COMP SCI 5801 The Structure Of Operating Systems** (LEC 3.0)

The hardware and software requirements for operating systems for uniprogramming, multiprogramming, multiprocessing, time sharing, real time and virtual systems. The concepts of supervisors, interrupt handlers, input/output control systems, and memory mapping are discussed in detail. Prerequisite: A "C" or better grade in Comp Sci 3800.

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**COMP SCI 5802 Introduction to Parallel Programming and Algorithms** (LEC 3.0)

Parallel and pipelined algorithms, architectures, network topologies, message passing, process scheduling and synchronization. Parallel programming on clusters. Cost, speedup and efficiency analysis. Prerequisite: A "C" or better grade in both Comp Sci 3800 and Comp Sci 2500.

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**COMP SCI 5803 Introduction to High Performance Computer Architecture** (LEC 3.0)

Overviews high performance architecture of computing systems and covers various architectural/hardware and software/algorithmic means that enhance performance. Uniprocessor and concurrent systems are investigated. Various computational models are studied and linked to commercial systems. Prerequisite: A "C" or better grade in both Comp Eng 3150 and Comp Sci 2500. (Co-listed with Comp Eng 5110).

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**COMP SCI 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**COMP SCI 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**COMP SCI 6010 Seminar** (RSD 1.0)

Discussion of current topics.

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**COMP SCI 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP SCI 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**COMP SCI 6099 Research Special Topics** (IND 0.0-16)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**COMP SCI 6100 Software Engineering II** (LEC 3.0)

A quantitative approach to measuring costs/productivity in software projects. The material covered will be software metrics used in the life cycle and the student will present topical material. Prerequisite: A "C" or better grade in Comp Sci 3100.

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**COMP SCI 6101 Software Requirements Engineering** (LEC 3.0)

This course will cover advanced methods, processes, and technique for discovering, analyzing, specifying and managing software requirements of a software system from multiple perspectives. It will discuss both functional and non-functional requirements analysis. Prerequisite: A "C" or better grade in Comp Sci 3100.

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**COMP SCI 6102 Model Based Systems Engineering** (LEC 3.0)

Provides the student with understanding of the use of models to represent systems and validate system architectures. The student will gain proficiency in using a systems modeling language and shifting systems engineering from a document centric to a model centric paradigm. Prerequisites: Graduate Standing. (Co-listed with SYS ENG 6542).

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**COMP SCI 6200 Algorithmics II** (LEC 3.0)

Covers selected classical and recent developments in the design and analysis of algorithms, such as sophisticated data structures, amortized complexity, advanced graph theory, and network flow techniques. Prerequisite: A "C" or better grade in Comp Sci 5200.

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**COMP SCI 6201 Theory Of Computation** (LEC 3.0)

Turing machines and other machines. Godel numbering and unsolvability results. Machines with restricted memory access and limited computing time. Recursive functions, computable functionals and the classification of unsolvable problems. Prerequisite: A "C" or better grade in Comp Sci 2200.

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**COMP SCI 6202 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Sys Eng 6217 and Eng Mgt 6410).

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**COMP SCI 6203 Network Information Analysis** (LEC 3.0)

Modeling techniques and analytical methods to study the interaction of information and networks focusing on models and properties of network structures, and diffusion of information over networks. Expected outcomes are systematic inference of information encoded in network structures, and effective methods to disseminate or gather information from networks. Prerequisites: A "C" or better grade in Comp Sci 5200.

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**COMP SCI 6204 Applied Graph Theory for Computer Science** (LEC 3.0)

This course covers advanced concepts in graph theory and their applications. Graphs offer an excellent modeling and analysis tool for solving a wide variety of real-life problems. Emphasis will be on understanding concepts, theory, and proof techniques, and how to develop "cool" and "elegant" solutions for applications. Students will conduct projects. Prerequisite: A grade of "C" or better in Comp Sci 5200.

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**COMP SCI 6300 Object-Oriented Database Systems** (LEC 3.0)

This course will include a study of the origins of object-oriented database manipulation languages, their evolution, currently available systems, application to the management of data, problem solving using the technology, and future directions. Prerequisite: A "C" or better grade in Comp Sci 5102.

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**COMP SCI 6301 Web Data Management and XML** (LEC 3.0)

Management of semi-structured data models and XML, query languages such as Xquery, XML indexing, and mapping of XML data to other data models and vice-versa, XML views and schema management, advanced topics include change-detection, web mining and security of XML data. Prerequisite: A "C" or better grade in Comp Sci 5300.

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**COMP SCI 6302 Heterogeneous and Mobile Databases** (LEC 3.0)

This course extensively discusses multidatabase systems (MDBS) and mobile data access systems (MDAS). Moreover, it will study traditional distributed database issues within the framework of MDBSs and MDASs. Prerequisite: A "C" or better grade in Comp Sci 5300.

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**COMP SCI 6303 Pervasive Computing** (LEC 3.0)

Pervasive computing aims to seamlessly integrate computing with our everyday activities, so that people do not need to be aware of computing artifacts. This course will introduce various techniques needed to realize pervasive computing, such as position tracking and ad-hoc networking. Prerequisite: A grade of "C" or better in one of Comp Sci 4600, Comp Sci 5600, or Comp Eng 5410.

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**COMP SCI 6304 Cloud Computing and Big Data Management** (LEC 3.0)

Covers facets of cloud computing and big data management, including the study of the architecture of the cloud computing model with respect to virtualization, multi-tenancy, privacy, security, cloud data management and indexing, scheduling and cost analysis; it also includes programming models such as Hadoop and MapReduce, crowdsourcing, and data provenance. Prerequisites: A grade of 'C' or better in both COMP SCI 5800 and either COMP SCI 5300 or COMP SCI 5402.

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**COMP SCI 6400 Advanced Topics In Artificial Intelligence** (LEC 3.0)

Advanced topics of current interest in the field of artificial intelligence. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in one of Comp Sci 5400, Comp Sci 5401 or Comp Eng 5310.

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**COMP SCI 6401 Advanced Evolutionary Computing** (LEC 3.0)

Advanced topics in evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory, capable of solving complex problems for which other techniques fail. Students will conduct challenging research projects involving advanced concept implementation, empirical studies, statistical analysis, and paper writing. Prerequisite: A "C" or better grade in Comp Sci 5401.

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**COMP SCI 6402 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 5001 Introduction to Data Mining. (Co-listed with Comp Eng 6302 and Sys Eng 6216).

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**COMP SCI 6404 Computer Graphics And Realistic Modeling** (LEC 3.0)

Algorithms, data structures, software design and strategies used to achieve realism in computer graphics of three-dimensional objects. Application of color, shading, texturing, antialiasing, solid modeling, hidden surface removal and image processing techniques. Prerequisite: A "C" or better grade in Comp Sci 5406.

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**COMP SCI 6405 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Sys Eng 6214 and Stat 6239).

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**COMP SCI 6406 Machine Learning in Computer Vision** (LEC 3.0)

Introduces machine learning fundamentals in current computer vision research. Topics include modeling complex data densities, regression and classification models, graphical models such as chains, trees, and grids, temporal models such as particle filtering and models for visual recognition such as deep learning. Students will implement select course topics. Prerequisite: A grade of "C" or better in either Comp Sci 5402 or Comp Sci 5404.

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**COMP SCI 6500 Theory Of Compiling** (LEC 3.0)

Properties of formal grammars and languages, language-preserving transformations, syntax-directed parsing, classes of parsing methods and the grammars for which they are suited, control flow analysis, and the theoretical framework of local and global program optimization methods. Prerequisite: A "C" or better grade in Comp Sci 5500.

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**COMP SCI 6600 Formal Methods in Computer Security** (LEC 3.0)

The course presents various vulnerabilities and threats to information in cyberspace and the principles and techniques for preventing and detecting threats, and recovering from attacks. The course deals with various formal models of advanced information flow security. A major project will relate theory to practice. Prerequisites: A grade of "C" or better in both Comp Sci 3600 and Comp Sci 5200.

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**COMP SCI 6601 Privacy Preserving Data Integration and Analysis** (LEC 3.0)

This course covers basic tools, in statistics and cryptography, commonly used to design privacy-preserving and secure protocols in a distributed environment as well as recent advances in the field of privacy-preserving data analysis, data sanitization and information retrieval. Prerequisite: A "C" or better grade in both Comp Sci 5300 and Comp Sci 3600.

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**COMP SCI 6602 Network Performance Analysis** (LEC 3.0)

Provides an introduction to performance modeling and analysis of computer networks. Topics include stochastic processes; performance measurement and monitoring; quantitative models for network performance, e.g., Markovian models for queues; simulation; and statistical analysis of experiments. Prerequisites: Comp Eng 5410 or Comp Sci 4600; Stat 3117 or 5643. (Co-listed with Comp Eng 6440).

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**COMP SCI 6603 Advanced Topics in Wireless Networks** (LEC 3.0)

Introduces the fundamentals and recent advances in wireless networking. Coverage includes cellular networks, wireless and mobile ad hoc networks, wireless mesh networks, sensor networks and wireless LANs with a focus on network operation. Special topics selected from the literature on wireless network security will also be addressed. Prerequisite: A "C" or better grade in Comp Sci 4600 or equivalent.

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**COMP SCI 6604 Mobile And Sensor Data Management** (LEC 3.0)

Architectures of mobile computing systems; Mobile-IP support in mobile computing systems; location data management, Broadcasting and indexing, replication control; caching, fault tolerance and reliability of mobile systems; adhoc and sensor routing schemes, key management. Prerequisite: Comp Sci 4601.

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**COMP SCI 6605 Advanced Network Security** (LEC 3.0)

Topics covered include network security issues such as authentication, anonymity, traceback, denial of service, confidentiality, forensics, etc. in wired and wireless networks. Students will have a clear, in-depth understanding of state of the art network security attacks and defenses. Prerequisite: A "C" or better grade in either Comp Eng 5420 or Comp Sci 4600.

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**COMP SCI 6800 Distributed Systems Theory And Analysis** (LEC 3.0)

Analysis of the problems of state maintenance and correctness in concurrent computing systems using formal methods such as Hoare Logic, Temporal Logic, and Symbolic Model Checking. Prerequisite: A "C" or better grade in Comp Sci 5800.

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**COMP SCI 6801 Topics in Parallel and Distributed Computing** (LEC 3.0)

Introduction of parallel and distributed computing fundamentals and advanced research topics. Students present research papers selected from the current literature on P&D computing paradigms. A term paper and oral presentation are required. Prerequisite: A "C" or better grade in Comp Sci 5802 or equivalent background. (Co-listed with Comp Eng 6110).

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## Economics

The department of economics has entered into a cooperative agreement with the department of economics of the University of Missouri-St. Louis to offer a master of arts in economics. A maximum of 12 graduate semester hours may be taken at Missouri S&T (with no more than 9 credit hours at the 4000-level).

## Management for Sustainable Business

This certificate in management for sustainable business addresses an identified need to provide science and engineering students with business knowledge and professional skills to further their careers in business sustainability. The certificate will focus on building knowledge and competencies, specifically in the area of environmental sustainability of a business organization. The proposed program will provide professionals with the skills necessary for rapidly advancing themselves in the workplace, and more importantly, rapidly advancing the general knowledge base and skill set in their professional workplaces.

The curriculum consists of the following:

ECON 6641	Advanced Foundations of Sustainability
ECON 6642	Global Eco- and Social-preneurship and Innovation
ECON 6643	Advanced Ethical Problems in a Global Environment
Choose one of the following:	
ECON 6440	Advanced Environmental and Natural Resource Economics
ECON 5532/ MIN ENG 5532	Advanced Mining Economics
ECON 6540	Advanced Energy Economics
ECON 5644	Creativity, Innovation, and Sustainability
ENG MGT 5320	Project Management
ENG MGT 5513	Energy and Sustainability Management Engineering
MIN ENG 5742	Environmental Aspects of Mining
MIN ENG 6735	Sustainability In Mining

**Bonnie J Bachman**, Professor  
PHD Rutgers University

**Michael C Davis**, Associate Professor  
PHD University of California-San Diego

**Mahelet Fikru**, Assistant Professor  
PHD Southern Illinois University-Carbondale

**Gregory Gelles**, Professor  
PHD West Virginia University

**Ana-Maria Ichim**, Assistant Professor  
PHD Louisiana State University

**Eun Soo Park**, Associate Professor  
PHD Northwestern University

**Radu Pუსlenghea**, Assistant Teaching Professor  
PHD University of Virginia

**Sarah Steelman**, Assistant Teaching Professor  
MA University of Missouri-Columbia

**Yishu Zhou**, Assistant Professor  
PHD University of Connecticut

**ECON 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department.  
Consent of instructor required.

**ECON 5001 Special Topics** (LEC 0.0 and LAB 0.0)  
This course is designed to give the department an opportunity to test a new course.

**ECON 5010 Seminar** (RSD 0.0-6.0)  
Discussion of current topics.

**ECON 5120 Advanced Micro and Macro Economics Essentials** (LEC 1.5)  
An introduction to the essentials of micro and macro economics for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit in this course cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

**ECON 5310 Advanced Mathematical Economics** (LEC 3.0)

Marginal analysis, calculus, and linear algebraic systems are applied in selected advanced topics in economics such as price theory, general equilibrium theory, input-output analysis, activity analysis, and game theory. This course is an advanced version of Econ 4310, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4310 and Econ 5310. Prerequisites: Econ 2100, 2200 and Math 1208, Math 3103.

**ECON 5330 Econometric Methods** (LEC 2.0 and LAB 1.0)

A survey of econometric topics and methods illustrated through real world applications. Includes least squares estimation, generalized least squares, two-stage least squares, simultaneous equations models, panel data and qualitative choice models. Students will use modern statistical software packages (STATA, R) to perform hands-on quantitative analysis. Prerequisites: Econ 2100 and Econ 2200, Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117 or Stat 5643.

**ECON 5337 Financial Mathematics** (LEC 3.0)

The course objective is to provide an understanding of the fundamental concepts of financial mathematics. Topics include pricing, assets-liability management, capital budgeting, valuing cash flow, bonds, futures, swaps, options. Preparation for the financial mathematics actuarial exam will be provided. Prerequisites: Math 1215 or Math 1221, Econ 1100 or Econ 1200, and one of the following: Stat 3111, Stat 3113, Stat 3115, Stat 3117 or Stat 5643. (Co-listed with Math 5737).

**ECON 5342 Advanced Finance** (LEC 3.0)

This course provides a rigorous and consistent presentation of the theory of financial decisions. Capital markets are analyzed under assumptions of risk aversion and uncertainty. Models of modern portfolio theory are discussed including the CAPM and the Modigliani-Miller analysis. This course is an advanced version of Econ 321, and will include additional research and project assignments. Credit cannot be obtained for both Econ 5160 and Econ 5342. Prerequisite: Econ 2100 or Econ 2200.

**ECON 5430 Advanced Cost-Benefit Analysis** (LEC 3.0)

Investigates the rationale for cost-benefit analysis within a free enterprise setting. Discussion of market efficiency and failure; determination of social costs and benefits; applications of cost-benefit analysis; and, problems remaining in theory and practice. This course is an advanced version of Econ 4430, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4430 and Econ 5430. Prerequisite: Econ 2100.

**ECON 5532 Advanced Mining Economics** (LEC 3.0)

Mining industry & national economics. Social & economics significance of mined commodities. Marketing of mined commodities. Innovation approaches to mine financing, project loans, and leasing. Mining feasibility studies, government influence & policy, mining industry foreign investment, investment strategies, mining taxation, cost predictions. Case Studies. (Co-listed with MIN ENG 5532).



**ECON 5644 Creativity, Innovation, and Sustainability** (LEC 3.0)

This interdisciplinary course examines the use of innovation as a competitive technological strategy with a sustainability perspective. It explores ways in which individuals, groups, and organizations can become more creative and how leadership and a culture of change can be implemented.

**ECON 5710 Advanced International Trade** (LEC 3.0)

Analysis of gains from trade; the effects of factor mobility; effects of trade restrictions on trade flow and income distribution; arguments for restricting trade; and effects of trade on economic development, employment and human capital development. This course is an advanced version of Econ 4710+D1194, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4710 and Econ 5710. Prerequisite: Econ 2100.

**ECON 5720 Advanced International Finance** (LEC 3.0)

Examination of the international monetary system, the Balance of Payments, the foreign exchange market, futures and options markets; foreign exchange and other risk management for firms, financing from a global perspective and direct foreign investment. This course is an advanced version of Econ 4720, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4720 and Econ 5720. Prerequisite: Econ 2200.

**ECON 5820 Advanced Labor Economics** (LEC 3.0)

Labor as a factor of production, collective bargaining, trade unionism, labor legislation, from the viewpoint of public policy. This course is an advanced version of Econ 4820, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4820 and Econ 5820. Prerequisite: Econ 2100 or Econ 2200.

**ECON 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ECON 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**ECON 6337 Financial Mathematics II** (LEC 3.0)

Continuation of Math 5737/Econ 5337. Topics include martingales and measures, stopping times, discrete and continuous time finance, Brownian motion, Ito calculus, stochastic differential equations, Black-Scholes-Merton formula, numerical procedures. Prerequisite: Math 5737 or Econ 5337. (Co-listed with Math 6737).

**ECON 6440 Advanced Environmental and Natural Resource Economics** (LEC 3.0)

Optimum use of renewable and non-renewable resources, public goods and common resources, externalities, and quality of the environment; emphasis on public policy related to environmental and natural resource economics. As an advanced version of Econ 4440, it will include additional research assignments. Credit can't be earned for both Econ 4440 and 6440. Prerequisite: Econ 2100.

**ECON 6540 Advanced Energy Economics** (LEC 3.0)

Market structures. World resource development. Supply and demand analysis on energy production and consumption within domestic and global settings. This course is an advanced version of Econ 4540, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4540 and Econ 6540. Prerequisite: Econ 2100.

**ECON 6641 Advanced Foundations of Sustainability** (LEC 3.0)

This interdisciplinary course is designed as an introduction to sustainability in commerce. It examines environmental, social, and economic issues in an organized context. Principles, processes and practices in sustainability will be explored. Project or written case study required.

**ECON 6642 Global Eco- and Social-preneurship and Innovation** (LEC 3.0)

This interdisciplinary course applies an entrepreneurial mindset to the environmental and social opportunities and challenges facing the global community. Topics are examined from multiple perspectives; nonprofit, hybrid, and for-profit organizations. Written case studies required. Research project required. Prerequisites: Econ 6641.

**ECON 6643 Advanced Ethical Problems in a Global Environment** (LEC 3.0)

Focuses on the international dimension of ethics including corporate responsibility from economic, social, and environmental perspectives. It addresses the ethical challenges of decision-making, stakeholder engagement, and governance at micro-(personal), and meso-(org), and macro-(systems) levels. Case studies will be included as part of the course.

## Electrical Engineering

The mission of the electrical engineering program, consistent with the Missouri S&T campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society's problems in the area of electrical engineering.

The electrical engineering program in the department of electrical and computer engineering offers graduate programs of study which lead to the M.S. degree (thesis and non-thesis options), the Ph.D. degree and the doctor of engineering degree. Both, the Rolla campus and the Engineering Education Center in St. Louis offer M.S. programs. Most graduate programs in electrical engineering normally include some specialization in one or more of the following six emphasis areas of electrical engineering.

## Emphasis Areas

### Circuits and Electronics

Topics include network analysis and synthesis, computer-aided circuit design, distributed circuits, communication circuits, and linear and nonlinear electronic circuits.

### Communications & Signal Processing

Topics include coding, information theory, modulation, detection, filtering for both analog and digital systems, signal processing, image processing and wireless.

### Controls and Systems

Topics include resilience control, wireless sensor/network design and networked control systems, process control, optimal control and estimation, robust control, neural networks, fuzzy logic based control as applied to control of vehicles, chemical processes, manufacturing, robotics, environmental systems and smart structural systems.

#### **Devices and Optics**

Topics include the semiconductor devices, microsystems, fiber optics and sensors, optical methods applied to structural monitoring, and optical/quantum computing.

#### **Electromagnetics**

Topics include electromagnetic compatibility and signal integrity for high-speed electronic systems, microwaves and applications to nondestructive testing and evaluation.

#### **Power**

Topics include power electronic converters, electric machines, electric motor drives, high voltage engineering, transportation electrification, application of computer methods to power system analysis and control, power system relaying and protection, and power quality load management.

## **Departmental Requirements**

### **Admission Requirements**

The nominal GPA requirement for admission to the M.S. degree program in this department is an undergraduate GPA of 3.3 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example, we cannot accept students who have only a diploma or engineering technology degree.

The ECE department requires ETS reported GRE scores and recommends the following:

ETS scoring after November 2011: Q+V=305, Q $\geq$  160, A/WR $\geq$  3.5

This GRE requirement may be waived if the applicant has an undergraduate GPA of 3.5 obtained from the courses offered by the electrical engineering or computer engineering program at Missouri S&T (must be minimum 18 credit hours).

For international students who are required to provide TOEFL scores, the ECE department has no preference as to the computer based TOEFL (CBT), internet based TOEFL (iBT), or paper based TOEFL (PBT). Recommended scores set by the department are 230 CBT, 88 iBT, and 570 PBT. Where TOEFL is not available, IELTS score of  $\geq$  6.5 is strictly required.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed on their admission. These conditions are generally imposed to make sure that students lacking a traditional electrical engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the Ph.D. program should meet or exceed all of the above recommendations and should have a graduate GPA of 3.5 or better. All Ph.D. applicants must provide at least three letters of recommendation. Exceptional applicants may apply directly to the Ph.D. program after completing the baccalaureate degree.

## **M.S. Degree Requirements**

Thesis option M.S. programs of study require a minimum of 21 credit hours of coursework exclusive of credit hours earned for thesis research. The thesis option degree is based on a combination of coursework and research. This option requires the student to find a faculty member willing to serve as advisor. This should be done as soon as possible so that the student and advisor will be able to formulate both a plan of coursework and a research project.

Non-thesis option M.S. program is based entirely on coursework. This option requires a minimum of 30 credit hours of coursework. Non-thesis students are assigned an initial advisor by the department, typically the associate chair for graduate studies. M.S. degree students, both thesis and non-thesis option, may change this degree option and advisors at any time with the consent of their current and new advisors.

### **M.S. Communication Requirements**

An M.S. student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

## **Doctoral Degree Requirements**

The two types of doctoral degrees offered by this department are the Doctor of Philosophy (Ph.D.) and the Doctor of Engineering (D.E.) with a strong emphasis on research with advisor. The primary difference between these two doctoral degrees is that the research portion of the D.E. degree is conducted as an internship with an industrial concern or government laboratory and is jointly supervised by an internship advisor employed by the cooperating organization and a faculty advisor employed by S&T. In contrast, the research portion of the Ph.D. degree is generally conducted on campus.

The doctoral program of study, for the Ph.D. degree or the D.E. degree, should include 90 credit hours (minimum 48 hours coursework and minimum 42 hours research) beyond the B.S. degree or 60 credit hours (minimum 24 hours coursework and minimum 36 hours research) beyond the M.S. degree.

### **Doctoral Communication Requirement**

A doctoral student is required to fulfill a zero credit hour communications requirement to demonstrate a sufficient communications capability to operate effectively at an advanced level in the professional engineering and scientific community. To fulfill this requirement, the advisor will

monitor the student's capability through one of the following exemplary activities during the program of study:

1. Authoring at least one accepted publication (major contribution to communication aspects)
2. Taking/transferring one graduate-level communication course
3. Possessing industrial or other professional experiences
4. Having completed example(s) listed above or equivalent before enrolling in the program
5. Other equivalent qualifications as identified by the advisor

## Research

Significant research, suitable for publication, is expected for students pursuing the thesis option M.S. or a doctoral degree. The student should work closely with their major advisor and their advisory committee to determine when these expectations are met. The length of research time and/or the number credit hours earned for thesis research will not automatically satisfy this requirement.

## Additional Information

Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the department's web page at <http://ece.mst.edu>. We can be contacted by telephone at 573-341-4519 or e-mail [ecegrad@mst.edu](mailto:ecegrad@mst.edu). For information about the Engineering Education Center in St. Louis, visit their web page at <http://eec.mst.edu>.

## Advanced Control Systems

This graduate certificate program is designed to provide specialized graduate level education in the area of advanced control systems.

### Admission

The advanced control systems graduate certificate program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the M.S. program in electrical engineering, provided that all other program prerequisites and admission requirements are met. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

### Curriculum

Students enrolled in this graduate certificate program will take two required courses and two elective courses. Alternative courses may be substituted with the departmental approval dependent on the availability of the courses listed below:

Required courses:

ELEC ENG 5300	Digital Control
ELEC ENG 6300	Linear Control Systems
Choose two of the following:	
ELEC ENG 5320	Neural Networks Control and Applications
ELEC ENG 5330	Fuzzy Logic Control
ELEC ENG 5350	Plantwide Process Control
ELEC ENG 5360	System Simulation And Identification
ELEC ENG 5380	Autonomous Mobile Robots
ELEC ENG 6310	Optimal Control And Estimation
ELEC ENG 6330	Robust Control Systems
ELEC ENG 6390	Current Topics In Control Theory
ELEC ENG 6335	Discrete-Time Neural Network Control
or ELEC ENG 6350 Neural Network Control of Nonlinear Continuous-time Systems	
ELEC ENG 5325	Applied Nonlinear Control
or ELEC ENG 632 Nonlinear Control Systems	

## Automation Engineering and PLC

This graduate certificate program is designed to provide specialized graduate level education in the area of automation engineering and PLC.

### Admission

The automation engineering and PLC graduate certificate program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status. If the four-course sequence is completed with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program in chemical engineering, electrical engineering, or mechanical engineering, provided that all other program prerequisites and admission requirements are met. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

### Curriculum

Students enrolled in this graduate certificate program will take two required courses and two elective courses. Alternative courses may be substituted with the departmental approval dependent on the availability of the courses listed below:

Required courses:

CHEM ENG 51 90/ ELEC ENG 5350	Plantwide Process Control
ELEC ENG 5340	Advanced PLC
Choose two of the following:	
CHEM ENG 51 40	
ELEC ENG 5345	PLC Motion Control
ELEC ENG 5870/ MECH ENG 5478	Mechatronics
MECH ENG 5449	Robotic Manipulators and Mechanisms
MECH ENG 5655	Manufacturing Equipment Automation

## Electric Machine and Drives

This graduate certificate program is designed to provide specialized graduate level education in the area of electric machine and drives.

### Admission

The electric machine and drives program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program and having a minimum of 24 months of post B.S. professional work experience that would normally require an engineering degree or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status; however, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program in electrical engineering if they apply. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

### Curriculum

Students enrolled in this graduate program will take two required courses and two elective courses. Alternative courses may be substituted with the departmental approval dependent on the availability of the courses listed below:

The following two courses must be taken:

ELEC ENG 5500	Electric Drive Systems
ELEC ENG 6500	Advanced Theory Of Electric Machines
A minimum of two of the following electric power systems courses must be taken:	
ELEC ENG 5550	Electric Power Quality
ELEC ENG 5300	Digital Control
ELEC ENG 5520	Power Electronics
ELEC ENG 5600	Interference Control in Electronic Systems
ELEC ENG 6001	Special Topics
ELEC ENG 6550	Power System Stability
ELEC ENG 6300	Linear Control Systems

Other courses approved by the electric machines and drives faculty may be substituted for any of the above listed courses on a case-by-case basis. The department's associate chair for distance education must approve the substitution prior to enrolling in the course.

## Electrical Power Systems Engineering

This graduate certificate program is designed to provide specialized graduate level education in the area of electric power systems engineering.

### Admission

The electrical power systems engineering program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program and having a minimum of 24 months of post B.S. professional work experience that would normally require an engineering degree or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status; however, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program in electrical engineering if they apply. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

### Curriculum

Students enrolled in this graduate certificate program will take two required courses and two elective courses. Alternative courses may be substituted with the departmental approval dependent of the availability of the courses listed below:

The following two electric power systems courses must be taken:

ELEC ENG 5540	Power Systems Engineering
ELEC ENG 5550	Electric Power Quality
A minimum of two of the following electric power systems courses must be taken:	
ELEC ENG 6300	Linear Control Systems
ELEC ENG 5570	Extra High Voltage Engineering
ELEC ENG 6540	Computer Methods In Power System Analysis
ELEC ENG 6550	Power System Stability
ELEC ENG 6560	Power System Protection
ELEC ENG 6570	Surge Phenomena In Power Systems
ELEC ENG 6580	Power System Operations

Other courses approved by the electric power systems faculty may be substituted for any of the above listed courses on a case-by-case basis. The department's associate chair for distance education must approve the substitution prior to enrolling in the course.

**Levent Acar**, Associate Professor  
PHD Ohio State University  
Control and systems, intelligent control with applications to robotics, neural network and fuzzy logic systems, large-scale systems and optimization.

**Ahmad Alsharoa**, Assistant Professor  
PHD Iowa State University

**Daryl G Beetner**, Professor<sup>1</sup>  
DSC Washington University  
Computer Engineering, parallel processing, hardware-software co-design, skin cancer detection, and electro-cardiology. Interests in electro-cardiology include body-surface mapping, the inverse problem, and risk-assessment.

**Rui Bo**, Assistant Professor  
PHD Univeristy of Tennessee-Knoxville  
Computation, optimization and economics in power system operation and planning, high performance computing and its application in power systems, electricity market simulation, evaluation and design.

**Minsu Choi**, Associate Professor  
PHD Oklahoma State University  
Computer architecture & VLSI, embedded systems, fault tolerance testing, quality assurance, reliability modeling & analysis, configurable computing, distributed systems, dependable instrumentation & measurement.

**Kristen Marie Donnell Hilgedick**, Associate Professor  
PHD Missouri Univeristy of Science & Technology  
Microwave nondestructive testing, modulated antennas/scatterers, terahertz methodologies and electronics design.

**Kelvin Todd Erickson**, Professor<sup>1</sup>  
PHD Iowa State University  
Chemical process control, advanced control algorithms, digital control, programmable logic controllers, system identification.

**Mina Esmaelpour**, Assistant Professor  
PHD Lehigh University

**Jun Fan**, Professor  
PHD University of Missouri-Rolla  
Intra-system electromagnetic compatibility, Radio-Frequency interference, signal/power integrity, high-speed printed circuit boards and packages.

**Mehdi Ferdowsi**, Professor  
PHD Illinois Institute of Technology  
Power electronics, power converters and electric drives.

**Jie Huang**, Assistant Professor  
PHD Clemson University  
Fiber optic sensors, laser machining, sensors and instrumentation for applications in harsh environments, microwave-photonic sensing imaging and spectroscopy.

**Ali Hurson**, Professor  
PHD University of Central Florida  
Parallel and distributed systems, databases, mobile-databases, pervasive and mobile computing.

**Chulsoon Hwang**, Assistant Professor  
PHD KAIST, Daejeon, Korea  
Signal and power integrity of IC/package/PCB system, electromagnetic modeling, time/frequency domain simulation/measurement techniques.

**Chang-Soo Kim**, Professor  
PHD Kyungpook National University  
Micro-and nano-sensors, bio-MEMS (Micro Electro Mechanical System), microsystems, sensor engineering, biomedical/agricultural engineering.

**DongHyun Kim**, Assistant Professor  
PHD Kaist, Korea

**Jonathan William Kimball**, Professor<sup>1</sup>  
PHD University of Illinois-Urbana  
Power electronics, energy harvesting, alternative energy, multi-phase converters.

**Kurt Louis Kosbar**, Associate Professor  
PHD University of Southern California  
Statistical communication theory, spread spectrum systems, computer aided design of communication systems, stochastic process theory, digital signal processing.

**Jagannathan Sarangapani**, Professor  
PHD University of Texas-Arlington  
Control of networks, embedded systems and resilience, sensors and neural network control, diagnostics/prognostics, cyber physical systems, event-triggered control.

**Sahra Sedighsarvestani**, Associate Professor  
PHD Purdue University-W. Lafayette  
Component-based software engineering and enterprise integration.

**Pourya Shamsi**, Associate Professor  
PHD University of Texas-Dallas  
Smart-grids, stability assessments in micro-grids, energy management, switching power converters, VHF/UHF dc-dc converters, and motor drives.

**Ronald Joe Stanley**, Professor  
PHD University of Missouri-Columbia  
Image processing, pattern recognition software methods, automation and medical informatics.

**Steve E Watkins**, Professor  
PHD University of Texas at Austin  
Fiber optic sensing, optical and electronic materials, electro-optic devices and Fourier optics.

**Cheng Hsiao Wu**, Professor  
PHD University of Rochester  
Quantum resistor network theory, semiconductor device modeling, DLTS measurement, optical computing.

**Donald C Wunsch II**, Professor<sup>1</sup>  
PHD University of Washington  
Adaptive critic designs, neural networks, fuzzy systems, surety, nonlinear adaptive control, intelligent agents, applications, financial engineering.

**Maciej J Zawodniok**, Associate Professor  
PHD University of Missouri-Rolla  
Embedded systems for cyber infrastructure, wireless sensor and ad hoc networks, and general wireless communications systems.

**Jiangfan Zhang**, Assistant Professor

PHD Lehigh University

Statistical signal processing for cyber-physical systems, Internet of Things, sensor networks, cybersecurity, smart grid, radar and sonar processing.

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**ELEC ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**ELEC ENG 5001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ELEC ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**ELEC ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Civ Eng 5070).

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**ELEC ENG 5099 Special Research And Thesis** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**ELEC ENG 5100 Advanced Electronic Circuits** (LEC 3.0)

Application of feedback theory, oscillators and frequency standards, precision analog techniques, low-power circuit design, interfacing sensors, designing for high reliability, electronics for harsh environments. Prerequisite: Elec Eng 3120.

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**ELEC ENG 5120 Communication Circuits** (LEC 3.0)

Analysis and design of circuits used in communication systems. Topics include RF semiconductor devices, low-noise amplifiers, mixers, modulators, crystal oscillators, AGC circuits, highpower RF amplifiers, phase-locked loops, impedance matching, and frequency-selective networks and transformers. Prerequisites: Elec Eng 3120.

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**ELEC ENG 5140 High-Frequency Amplifiers** (LEC 3.0)

Analysis and design of high frequency amplifiers. Topics include parameter conversions, activity and passivity, stability criteria, device operating conditions, Smith chart usage, matching networks, microstrip, scattering parameters, and practical applications. Prerequisites: Elec Eng 3120, 3600.

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**ELEC ENG 5150 Photovoltaic Systems Engineering** (LEC 3.0)

Physics and characteristics of photovoltaic (solar) cell technologies, electronic control of alternative energy sources, site selection, array design, energy storage methods, electrical code compliance, stand-alone systems, grid-intertie systems, legal and economic considerations. Prerequisite: Senior or graduate standing in Science or Engineering.

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**ELEC ENG 5160 Computer-Aided Network Design** (LEC 3.0)

Analysis and design of active and passive electric networks. Theory and computer application, including methods for automatic formulation of network state equations, network tolerance, network optimization, and device modeling. Prerequisites: Elec Eng 3100.

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**ELEC ENG 5170 Introduction To Circuit Synthesis** (LEC 3.0)

Fundamentals of linear circuit theory. Matrix formulation, and topological methods as applied to circuit analysis. Properties of network functions and introductory network synthesis. Prerequisites: Elec Eng 3430.

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**ELEC ENG 5200 Classical Optics** (LEC 3.0)

Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 2222 and Physics 2135 or 2111. (Co-listed with Physics 4503).

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**ELEC ENG 5210 Fourier Optics** (LEC 3.0)

Applications of Fourier analysis and linear systems theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or Physics 4211. (Co-listed with PHYSICS 5503).

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**ELEC ENG 5220 Fiber And Integrated Optics** (LEC 3.0)

Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Physics 5513).

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**ELEC ENG 5250 Optical Computing** (LEC 3.0)

Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisite: Comp Eng 2210 or equivalent. (Co-listed with Comp Eng 5230).

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**ELEC ENG 5270 Smart Materials And Sensors** (LEC 2.0 and LAB 1.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5529, Mech Eng 5229 and Civ Eng 5118).

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**ELEC ENG 5300 Digital Control** (LEC 3.0)

Analysis and design of digital control systems. Review of ztransforms; root locus and frequency response methods; state space analysis and design techniques; controllability, observability and estimation. Examination of digital control algorithms. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5320 Neural Networks Control and Applications** (LEC 3.0)

Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of Control. Case studies and a term project. Prerequisites: Elec Eng 3320.

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**ELEC ENG 5325 Applied Nonlinear Control** (LEC 3.0)

Review of State Variable Models, Nonlinear Model and Phenomena, Lyapunov Stability, Phase Plane Analysis, Feedback Linearization, Sliding Mode and Backstepping Control, and Control Applications Prerequisite: Elec Eng 3320 or graduate standing.

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**ELEC ENG 5330 Fuzzy Logic Control** (LEC 3.0)

A mathematical introduction to the analysis, synthesis, and design of control systems using fuzzy sets and fuzzy logic. A study of the fundamentals of fuzzy sets, operations on these sets, and their geometrical interpretations. Methodologies to design fuzzy models and feedback controllers for dynamical systems. Various applications and case studies. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5340 Advanced PLC** (LAB 1.0 and LEC 2.0)

Advanced programmable logic controller (PLC) programming, function block, structured text, function chart, sequencer. Factory communications, system simulation, human-machine interface (HMI) programming. Advanced PID control. Network security and reliability. Class-wide project. Prerequisite: Elec Eng 3340.

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**ELEC ENG 5345 PLC Motion Control** (LEC 2.0 and LAB 1.0)

Factory automation motion control integrated with programmable logic controllers, servo control, variable-speed drive control, PackML state model, sizing motors and drives, machine safety, and experience with commercial hardware/software. Laboratory exercises on small-scale standard applications such as coordinated motion of multiple axes and camming. Prerequisite: Elec Eng 3340.

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**ELEC ENG 5350 Plantwide Process Control** (LEC 3.0)

Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Chem Eng 5190).

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**ELEC ENG 5360 System Simulation And Identification** (LEC 3.0)

Computationally efficient methods of digital simulation of linear systems. Non-parametric identification. Parametric identification with least squares and recursive least squares algorithms. Algorithms programmed using MATLAB. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5370 Introduction to Neural Networks and Applications** (LEC 3.0)

The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Sys Eng 5212).

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**ELEC ENG 5380 Autonomous Mobile Robots** (LEC 3.0)

This course will provide an introduction to mobile robots and current approaches to robot autonomy. Topics include mobile robot systems, modeling and control, sensors and estimation, localization and mapping, and motion planning. Prerequisites: Elec Eng 3320 or equivalent and Stat 3117 or equivalent.

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**ELEC ENG 5400 Digital Signal Processing II** (LEC 3.0)

Spectral representations, sampling, quantization, z-transforms, digital filters and discrete transforms including the Fast Fourier transform. Prerequisites: Elec Eng 3410.

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**ELEC ENG 5420 Communications Systems II** (LEC 3.0)

Random signals and their characterization; noise performance of amplitude, angle and pulse modulation systems; digital data transmission; use of coding for error control. Prerequisite: Elec Eng 3430.

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**ELEC ENG 5430 Wireless Networks** (LEC 2.0 and LAB 1.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Elec Eng 3430 or Comp Eng 3150. (Co-listed with Comp Eng 5430 and Sys Eng 5323).

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**ELEC ENG 5440 Stochastic Signal Analysis I** (LEC 3.0)

Introduction to the application of probabilistic models to typical electrical engineering problems. Topics include: methods for describing random voltages, random digital signals, correlation, linear mean-square estimation, linear transformation of random digital signals, and bit-error rate calculation for communication systems. Prerequisites: Math 3304 and Elec Eng 2120.

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**ELEC ENG 5450 Digital Image Processing** (LEC 3.0)

Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430.(Co-listed with Comp Eng 5450).

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**ELEC ENG 5460 Machine Vision** (LEC 3.0)

Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Comp Eng 5460).

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**ELEC ENG 5500 Electric Drive Systems** (LEC 3.0)

Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Prerequisites: Elec Eng 3500 and Elec Eng 3320.

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**ELEC ENG 5510 Electric-Drive Vehicles** (LEC 3.0)

Course covers introductory topics related to understanding/analysis of electric, hybrid/plug-in hybrid power trains. Classification of hybrid drivetrains, driving cycles, energy storage systems, mechanical coupling devices, automotive applications of fuel cells and introduction to power converters. Prerequisite: Senior standing and Physics 2135.

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**ELEC ENG 5520 Power Electronics** (LEC 3.0)

Analysis, design, modeling, and control of switching mode power converter circuits for ac-dc, dc-dc, dc-ac, and ac-ac conversion. Power semiconductor devices, passive components, and non-ideal sources and loads. Applications to industry, consumer goods, electric vehicles, and alternative energy. Prerequisite: Elec Eng 3100.

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**ELEC ENG 5521 Power Electronics Laboratory** (LAB 2.0)

An introduction to power electronic circuits is presented. Students will construct several dc/dc, dc/ac and ac/dc converters. Various switching algorithms, including pulse width modulation, delta modulation, and hysteresis control will be developed to regulate and control the respective circuits. Prerequisite: Co-requisite Elec Eng 5520.

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**ELEC ENG 5540 Power Systems Engineering** (LEC 3.0)

Network analysis applied to power systems; the load flow concept; economic operation of power systems; synchronous machine reactances and transient stability; symmetrical components and asymmetrical faults; protective relaying. Prerequisite: Elec Eng 3540.

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**ELEC ENG 5550 Electric Power Quality** (LEC 3.0)

Definitions of power quality, types of power quality problems; sources of sags, transient overvoltages and harmonics; distribution overcurrent protection methods and their effect on power quality and reliability; harmonic analysis, principles of controlling harmonics, devices for filtering harmonics; power quality improvement methods. Prerequisite: Elec Eng 3500 or Elec Eng 3540.

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**ELEC ENG 5570 Extra High Voltage Engineering** (LEC 2.0 and LAB 1.0)

The physical phenomena associated with high voltage dielectric breakdown are presented. Methods of generating and measuring high voltages and currents are explained. Demonstration of design and performance. Field trips to companies for laboratory testing of high voltage according to industry standards will serve as the lab part of the course. Prerequisite: Senior standing.

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**ELEC ENG 5600 Interference Control in Electronic Systems** (LEC 3.0)

Principles of high frequency effects in PCBs and components, generation of unwanted radio-frequency (RF) signals by ICs, RF radiation mechanisms, shielding, and immunity against electrostatic discharge and RF signals. Prerequisites: Elec Eng 3430 and 3600.

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**ELEC ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design** (LEC 3.0)

Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Comp Eng 5620).

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**ELEC ENG 5630 Wave Propagation and Transmission Lines** (LEC 3.0)

The materials in this course are intended to provide a) follow up electromagnetics related courses, b) electromagnetics related career including RF design and c) a graduate degree in electromagnetic related fields an in-depth understanding of the basics of wave propagation and transmission lines. Prerequisite: Elec Eng 3600.

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**ELEC ENG 5640 Antennas and Propagation** (LEC 3.0)

Propagated fields of elemental dipole, directivity and gain, radiation resistance, the half-wave dipole, wire antennas, arrays, broadband antennas, aperture antennas, horn antennas, and antenna temperature. Prerequisite: Elec Eng 3600.

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**ELEC ENG 5650 Microwave and Millimeter Wave Engineering and Design** (LEC 3.0)

Introduce senior and graduate students to the concept of microwave and millimeter wave engineering and passive component design such as waveguide, cavities, couplers, detectors, mixers, etc., including network theory and scattering matrix. Finally, their specific application in the design of various microwave circuits will be discussed. Prerequisites: Elec Eng 3600.

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**ELEC ENG 5660 Microwave Principles For Mixed-Signal Design** (LEC 3.0)

Transmission lines; coupled transmission lines; microwave network analysis; impedance matching and tuning; design of microwave amplifiers and oscillators. Prerequisite: Elec Eng 3600.

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**ELEC ENG 5670 Nondestructive Testing** (LEC 3.0)

Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Met Eng 5510).

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**ELEC ENG 5680 Introduction to Radar Systems** (LEC 3.0)

The objective of this course is to introduce senior and graduate students to various radar system principles, designs and applications (e.g., pulse, frequency-modulated, chirp, Doppler radars). Topics related to signals, systems, noise, resolution, multiple sampling, different imaging modalities, and remote sensing will also be discussed. Prerequisites: Elec Eng 3400 and Elec Eng 3600.

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**ELEC ENG 5810 Computational Intelligence** (LEC 3.0)

Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Comp Eng 5310 and Sys Eng 5211).

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**ELEC ENG 5870 Mechatronics** (LAB 1.0 and LEC 2.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Comp Eng 5820).

**ELEC ENG 5880 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Comp Eng 5880).

**ELEC ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ELEC ENG 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ELEC ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**ELEC ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**ELEC ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**ELEC ENG 6099 Special Research And Thesis** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**ELEC ENG 6140 Advanced RF & Time Domain Measurements** (LAB 1.0 and LEC 2.0)

Advanced measurement techniques and instrumentation: Oscilloscopes (Real time and sampling, A/D conversion errors, Probing, Jitter, Noise), Spectrum analyzer (concepts, applications), Network Analyzer (concepts, calibration), Impedance measurements. Lab experiments are a main part of this class. Prerequisite: Graduate standing.

**ELEC ENG 6150 Signal Integrity, High Speed Digital and RF Design Laboratory** (LAB 3.0)

This is an RF and digital electronics design class. Student groups will design, manufacture and test RF and/or digital circuits during the class. Besides this project work the lecture part will emphasize circuit design, layout, parasitic effects and design for testability. Prerequisite: Elec Eng 3600.

**ELEC ENG 6200 Electromagnetic Optics** (LEC 3.0)

Propagation, control, and modulation of laser radiation. Topics include optical polarization, interference, layered and anisotropic media, electro-optic devices, acousto-optic devices, and nonlinear optics. Prerequisite: Elec Eng 3600 or Physics 4211.

**ELEC ENG 6240 Semiconductor Devices** (LEC 3.0)

Properties of semiconductors, junctions and transistors; high frequency and high-current effects; recombination processes; field-effect devices, semiconductor devices and microcircuits. Prerequisite: Graduate status in Elec Eng.

**ELEC ENG 6260 Integrated Microsystems Engineering** (LEC 1.5 and LAB 1.5)

Theory and practice of multidisciplinary integrated microsystem technologies. The topics include (1) micromachining technology, (2) review of mechanical, optical, microfluidic and (bio) chemical microsensors and microactuators, (3) hands-on lab session for design, fabrication, and characterization of microsystems. Prerequisite: Graduate standing.

**ELEC ENG 6290 Advanced Topics in Optics and Devices** (LEC 3.0)

Advanced topics of current interest in optics and devices. Selected topics include semiconductor materials, electronic devices, wave-based sensing, fiber optic systems, optoelectronics, and photonic engineering. Prerequisite: Graduate Standing.

**ELEC ENG 6300 Linear Control Systems** (LEC 3.0)

Review of linear algebra, state variable formulations, solutions of state equations; controllability and observability; multivariable systems, matrix-fraction decompositions; design of state and output feedback controllers and observers; introduction to calculus of variations; linear quadratic regulators. Prerequisite: Elec Eng 3320.

**ELEC ENG 6310 Optimal Control And Estimation** (LEC 3.0)

Review of linear quadratic regulators (LQR), LQR extensions; constrained optimization (Pontragin's minimum principle); review of probability theory and random processes; optimal prediction and filters; frequency domain properties of LQR and Kalman filters; linear quadratic Gaussian (LQG) control; model uncertainties, frequency shaping, LQG/LTR design methodology. Prerequisite: Elec Eng 6300.

**ELEC ENG 6320 Nonlinear Control Systems** (LEC 3.0)

Numerical solution methods, describing function analysis, direct and indirect methods of Liapunov stability, applications to the Lure problem - Popov circle criterion. Applications to system design and feedback linearizations. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6330 Robust Control Systems** (LEC 3.0)

Performance and robustness of multivariable systems, linear fractional transformations, LQG/LTR advanced loop shaping, Youla parameterization,  $H_\infty$  (subscript infinity) optimal control, mixed  $H_2$  (subscript 2) and  $H_\infty$  (subscript infinity) control, controller synthesis for multiple objective optimal control, linear matrix inequalities theory and case studies. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6335 Discrete-Time Neural Network Control** (LEC 3.0)

Neural network topologies, universal function approximation property, background on Lyapunov stability & dynamic systems, control of a class of nonlinear systems using single and multilayer neural networks, feedback linearization, strict & nonstrict feedback systems, MIMO system, system identification, output feedback control, and hardware implementation. Prerequisites: Elec Eng 6300.

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**ELEC ENG 6350 Neural Network Control of Nonlinear Continuous-time Systems** (LEC 3.0)

Neural network topologies, universal function approximation property, background on Lyapunov stability and dynamic systems, control of a class of nonlinear systems and robot manipulators, feedback linearization, backstepping control, force control, neural observers, decentralized neural network control, neural network-based optimal control and applications. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6360 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

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**ELEC ENG 6370 Adaptive Control** (LEC 3.0)

Intro to adaptive control, Lyapunov stability, positive real and strictly positive real, Kalman-Yukabovich lemma, system identification, direct/indirect adaptive control, adaptive observers, adaptive control design, nonlinear adaptive design tools-adaptive control with multiple models, adaptive neural network control, decentralized adaptive control design. Prerequisites: Elec Eng 6300.

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**ELEC ENG 6390 Current Topics In Control Theory** (LEC 3.0)

Topics of current interest in control theory literature. Offered as interest and demand warrant. Prerequisite: Consent of instructor.

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**ELEC ENG 6400 Advanced Digital Signal Processing** (LEC 3.0)

Continuation of Elec Eng 5400. Effects of discrete noise sources in digital signal processing; discrete spectral analysis of random signals; discrete time signal detection, estimation, and filtering algorithms. Prerequisites: Elec Eng 5400 or Elec Eng 5420; Elec Eng 5440 or Stat 5643.

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**ELEC ENG 6410 Information Theory And Coding** (LEC 3.0)

Principles of information generation, transmission and processing; quantitative measure of information, entropy source encoding; channels; mutual information; channel capacity; Shannon's second theorem for discrete channels; introduction to coding for error controls; continuous information sources. Prerequisites: Elec Eng 5420 or Elec Eng 5440 or Stat 5643.

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**ELEC ENG 6420 Wireless Communications** (LEC 3.0)

Introduction to the principle of wireless communication systems. Topics include: wireless channel characteristics, cellular concepts, channel capacity analysis, transceiver architectures, diversity techniques, multiple access schemes, and practical wireless systems. Prerequisite: Elec Eng 5420 or Elec Eng 5440 or equivalent.

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**ELEC ENG 6430 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Sys Eng 6324).

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**ELEC ENG 6440 Stochastic Signal Analysis II** (LEC 3.0)

Continuous-time stochastic signals, multi-dimensional signals, Wiener and matched filters, LMS equalization, non-linear systems with random inputs, spectral estimation and Markov chains. Prerequisites: Stat 5643 or Elec Eng 5440.

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**ELEC ENG 6450 Statistical Decision Theory** (LEC 3.0)

Classical detection and estimation theory with applications; hypothesis testing, detection of known signals, matched filter receiver implementation, detection of signals with unknown parameters, sequential and nonparametric detection, detection of stochastic signals: Parameter estimation theory with application to modulation. Prerequisite: Elec Eng 5440.

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**ELEC ENG 6490 Advanced Topics In Communications** (LEC 3.0)

Advanced topics of current interest in communications and signal processing such as spread spectrum, digital processing of communications, speech, and radar signals, applications of pattern recognition, communications networks, specialized coding topics. Repeatable for additional credit toward degree each time a different subtitle offered. Prerequisite: Elec Eng 5420 or 5440.

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**ELEC ENG 6500 Advanced Theory Of Electric Machines** (LEC 3.0)

Energy conversion, reference frame theory, transient and dynamic modeling of ac machines, simulation of ac machines, parameter identification, model-order reduction, advanced topics depending on semester taught. Prerequisite: Elec Eng 3500.

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**ELEC ENG 6510 Advanced Electric Drive Vehicles** (LEC 3.0)

This course covers an entire range of advanced topics related to the analysis, design, control, simulation, and optimization of electric, hybrid, and plug-in hybrid power-trains including the automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Prerequisite: Elec Eng 5500 or Elec Eng 5520.

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**ELEC ENG 6520 Advanced Power Electronics** (LEC 3.0)

The purpose of this course is to cover selected areas of power electronics in greater depth. The topics covered include small signal analysis of power converters, voltage- and current- mode control, soft switching techniques, power factor correctors, multi-level converters, and PWM techniques. Prerequisite: Elec Eng 5520.

**ELEC ENG 6525 Power Converter Modeling and Design** (LEC 3.0)

Students will integrate electrical, magnetic, and thermal modeling techniques into a design process for switching power converters. A variety of applications will be considered, including dc-dc, ac-dc, and dc-ac converters over a wide power range. Prerequisite: Elec Eng 5520.

**ELEC ENG 6530 Power System Reliability** (LEC 3.0)

Reliability definition and measures. Probability concepts and Markov chains. Failure models and availability models. Generator system reliability. Loss of load probability method. Evaluation of transmission network reliability. Analysis of the electric power system reliability. Prerequisite: Stat 5643 or Elec Eng 5420.

**ELEC ENG 6540 Computer Methods In Power System Analysis** (LEC 3.0)

Algorithms for large scale system solution, non-linear systems, ordinary differential equations, eigenvalue problems, modal information, and optimization. Applications to power systems analysis. Prerequisite: Elec Eng 3540 or similar course.

**ELEC ENG 6550 Power System Stability** (LEC 3.0)

Synchronous machine theory and modelling; AC transmission; power system loads; excitation systems; control of active and reactive power; small signal stability; transient stability; voltage stability; mid-term and long-term stability; subsynchronous oscillations; stability improvement. Prerequisite: Elec Eng 3540 or similar course.

**ELEC ENG 6560 Power System Protection** (LEC 3.0)

Protective relaying incorporating electromechanical, solid state and computer relaying methods for high voltage transmission systems; instrument transformers; generator, transformer, line and bus protection; effect of system grounding; pilot protection and out of step relaying principles. Prerequisite: Elec Eng 5560 and 5540.

**ELEC ENG 6565 Power System Protection II** (LEC 3.0)

Protective relaying advanced topics focusing on methods for generation and high voltage transmission systems; generator, motor, transformer, transmission line and bus protection; pilot protection and out of step relaying principles; and NERCPRC (Protective Relay and Control) reliability standard requirements. Prerequisite: Elec Eng 6560.

**ELEC ENG 6570 Surge Phenomena In Power Systems** (LEC 3.0)

Study of transmission system insulation, distributed constant lines, terminations, multiple reflections, lightning performance, characteristics of sustained and switching overvoltages, surge voltages due to system faults, energizing and reclosing of circuit breakers. Methods of reducing overvoltages to acceptable levels. Prerequisite: Elec Eng 5540.

**ELEC ENG 6580 Power System Operations** (LEC 3.0)

Optimal dispatch operations, economic loading of power plants, mathematical optimization, locational marginal pricing, optimal power flow; effect of hydro and wind power plants on system economics; contingency analysis and system security, state estimation. Prerequisite: Elec Eng 5540.

**ELEC ENG 6600 Advanced Electromagnetics I** (LEC 3.0)

Review of Maxwell's equations, constitutive relations, and boundary conditions. Wave propagation and polarization. Vector magnetic and electric potentials. Equivalent representations of fields, Babinet's principle. Circular waveguides. Green's functions. Prerequisite: Elec Eng 3600 or equivalent undergraduate electromagnetics course.

**ELEC ENG 6610 Electromagnetic Waves II** (LEC 3.0)

Circular waveguides, circular cavities, scattering by cylinders, apertures in cylinders, spherical cavities, orthogonality relationships, source of spherical waves, scattering by spheres, perturbational and variational techniques, microwave networks, probes in cavities, and aperture coupling to cavities. Prerequisite: Elec Eng 6600.

**ELEC ENG 6630 Computational Electromagnetics** (LEC 3.0)

Differential-equation based numerical methods-finite element, finite-difference, and finite-difference time-domain-for solving static and dynamic equations of electromagnetics. Applications considered are multi-conductor transmission lines, Maxwell's equations for radiation and scattering, and electric machinery. Prerequisite: Elec Eng 3600.

**ELEC ENG 6640 Advanced Topics in Antenna Analysis and Design** (LEC 3.0)

Introduction and discussion of advanced antenna design issues including: polarization, antenna synthesis and source modeling, broadband antennas, aperture and microstrip antenna simulation and design, and antenna pattern measurement techniques including near-field to far-field transformation. Prerequisite: Elec Eng 5640 or equivalent.

**ELEC ENG 6830 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Sys Eng 6214, Comp Sci 6405 and Stat 6239).

## Engineering Management

Engineering management is the art and science of planning, organizing, allocating resources, and directing and controlling engineering activities. The field of engineering management has become recognized as a professional discipline with a critical role in the modern society. Graduates develop innovative and integrated solutions to problems that arise at the convergence of engineering and business.

Graduate programs leading to the M.S. and Ph.D. degrees are offered in engineering management. The discipline involves designing, operating and continuously improving systems by integrating engineering and management knowledge. This integration starts with an awareness of customer needs and market conditions. It then seeks to optimize

the use of people, equipment, money and information to achieve desired objectives. The discipline also seeks to develop students into individuals with leadership potential who can achieve high quality results in an ethical manner and with respect for the environment. The major goal of entering students is to enhance the usefulness of their previously acquired technical background. This is accomplished through coursework and research designed to expand knowledge of the management and operation of organizations in today's competitive environment. This broader understanding is further enhanced with the opportunity to acquire specialized knowledge in many areas that exist at the interface between the classical engineering and management disciplines.

The engineering management department has produced over 6,200 graduates at the B.S., M.S., and Ph.D. level since its inception in 1968. The engineering management and systems engineering department is one of only a few institutions in the world that offers B.S., M.S., and Ph.D. degrees in engineering management. The B.S. in engineering management is fully ABET accredited and the M.S. in engineering management has been certified by the American Society of Engineering Management. Graduates have been successful in working at the intersection of technology, engineering, and management to produce outstanding results.

## Requirements for Completion

Students following their approved program of study will be assured of graduation upon maintenance of good academic standing. A minimum of 30 units of course work from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a C grade or better in each course. Accumulation of more than 10 hours of "C" or "F" results in dismissal from the program. A maximum of nine hours of course work for M.S. degrees may be transferred from universities outside the University of Missouri System. Such credits for transfer must have been registered as graduate courses when they were taken. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. It is the responsibility of each student to apply for graduation with the Missouri S&T registrar's office during his or her last semester. Assistance on this final step can be provided by the engineering management and systems engineering department.

## Departmental Laboratories

The department has several "hands on" laboratories that have both a research and teaching focus. Each of our labs is directed by faculty members that work closely with students to enhance their learning experience. The description below gives a brief introduction that will help you understand the purpose of each lab.

### Smart Engineering Systems Lab (SESL)

The department established the Smart Engineering Systems Lab (SESL) to develop approaches in building complex systems that can adapt in the environments in which they operate. The term "smart" in the context indicates physical systems that can interact with their environment and adapt to changes both in space and time by their ability to manipulate the environment through self-awareness and perceived models of the world based on both quantitative and qualitative information. The emerging fields of artificial neural networks, fuzzy logic, evolutionary programming, chaos, wavelets, fractals, complex systems, and virtual reality provide essential tools for designing such systems.

The focus of the SESL is in developing smart engineering architectures that integrate and/or enhance the current and future technologies necessary for developing smart engineering systems while illustrating the real life applications of these architectures. The smart engineering systems design and operations cut across a diversity of disciplines, namely manufacturing, electrical, computer, and mechanical, biomedical, civil and other related fields such as applied mathematics, cognitive sciences, biology and medicine. Current research is on developing new models and tools for building complex systems architectures that are intelligent, modular, and adaptive.

### Design Engineering Center (DEC)

The center is one of the outreach arms of the engineering management and systems engineering department. The focus is on research and service activities in support of the educational goals of the department through externally funded projects. Current areas of research include total quality management, concurrent engineering, Taguchi Methods®, quality engineering, the product development process, and design optimization.

### Laboratory for Investment and Financial Engineering

The goal of the Laboratory for Investment and Financial Engineering is to develop techniques and computational tools for increasing investment and capital return while managing and reducing financial risk. This involves research into stocks and financial derivatives (options, futures, forwards, and swaps), financial risk and uncertainty, financial forecasting, market efficiency and behavioral finance, fundamental and technical analysis, equity valuation, real options, and engineering economics. In cooperation with the Smart Engineering Systems Lab, research in the lab may also involve the use of smart and intelligent systems, such as neural networks, fuzzy logic, genetic and evolutionary algorithms, expert systems, intelligent agents, artificial life, chaos and fractals, and dynamic and complex systems. Data mining, principal component analysis and various other forms of applied statistics are also used. Members of the lab have access to financial data and various financial modeling software packages.

### The Virtual and Augmented Reality Systems Engineering Lab (VASEL)

The Virtual and Augmented Reality Systems Engineering Lab (VASEL) has been established to complement ongoing and future research work within the department, the S&T campus and across the UM system. The research conducted in this lab will address current and future challenges faced at the boundaries and interfaces of science, technology and engineering research that are essential for the next level of scientific advances to address societal needs. These challenges are found at the nexus of various domains and require experts from all backgrounds of science and engineering to facilitate research leading to the emergence of new disciplines and the generation of knowledge, particularly in the areas of complex systems design and development.

The focus of the VASEL is the research and development of techniques and platforms that are essential to understanding the complementary and competitive teaming of humans with natural and engineered systems. This includes design and evaluation of human response to extreme events such as earthquakes and floods which informs our understanding of developing protocols to address these natural events. Research involving human response to manufactured events such as fires, shootings and even cyber-attacks similarly will lead to engineered strategies facilitated by the virtual environments used as experimental platforms.

## Additional Information

For additional information you can call our main department phone at 573-341-4572 or you can visit our web page at <http://emse.mst.edu/>.

## Master of Science Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: Regular status: 3.0 cumulative
- Graduate Record Exam (GRE): All students must submit current GRE scores. Students successfully completing one of the department's graduate certificates with a grade of B or better in all the certificate courses can be admitted without the GRE.
- Regular status:  $V+Q \geq 1100$ ,  $A \geq 4.0$  (former scoring) or  $V \geq 155$ ,  $Q \geq 148$ ,  $A \geq 4.0$
- Condition: Student must earn B or better in each of first four graduate (5000 or 6000 level) classes after conditional admission.
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.
- Regular status: 580/237/90
- Statement of Purpose: All applicants must submit a statement of purpose.
- Financial Support: Students in conditional status are not eligible for financial support from the department.
- Three reference letters

The M.S. degree program is offered on the Rolla campus and several locations including the Missouri S&T Global - St. Louis, Fort Leonard Wood (restricted to Engineer Captain's Career Course), and by distance education throughout the United States and selected international locations. Distance course lectures are archived upon completion of the lecture and all lectures are available to students through streaming video during the semester for review. These courses can be reached from anywhere at any time. It is feasible to obtain a Missouri S&T non-thesis M.S. degree regardless of your location.

The M.S. non-thesis program requires completion of at least 10 three-credit hour courses approved by the academic advisor. The M.S. with thesis option requires 30 credit hours including the thesis. All students are required to take the following:

### Core Courses

ENG MGT 5111	Management for Engineers and Scientists
ENG MGT 5320	Project Management
ENG MGT 5412	Operations Management Science
ENG MGT 6211	Advanced Financial Management

Students are then encouraged to identify an emphasis area depending on their interests and to choose available courses from the selected area. However, courses can be chosen from more than one emphasis area. Students have the option to take up to two out-of-department elective courses.

Students must submit a typed Form I to the EMSE graduate office by the beginning of the semester of their 15th credit hour. Links to forms are available at: <https://grad.mst.edu/currentstudents/forms/>. Thesis students cannot register for Graduate Research (ENG MGT 6099) until

their Form I is on file. If students vary from Form I, they must file a Form I-A. Non-thesis students must take three 6000-level courses. Thesis students must take two 6000-level courses (in addition to ENG MGT 6099). Students must meet all requirements for graduation as specified in the Graduate Catalog for engineering management. A graduate student already holding or completing a master's degree may obtain a second M.S. in engineering management by completing at least an additional 24 credit hours of work.

## Doctor of Philosophy Admission Standards

- B.S. in engineering, or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: M.S. GPA = 3.5
- Graduate Record Exam (GRE): All students must submit current GRE scores.  $V+Q \geq 1100$ ,  $A \geq 4.0$  (former scoring) or  $V \geq 155$ ,  $Q \geq 148$ ,  $A \geq 4.0$
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.
- Regular status: 580/237/90
- Statement of Purpose: All applicants must submit a statement of purpose.
- Three reference letters

A candidate for the Ph.D. in engineering management must complete the equivalent of at least three years of full-time work beyond the bachelor's degree. The content of all Ph.D. programs is individually structured by the student in consultation with and approved by the student's advisory committee. All requirements for the degree must normally be completed within an eight-year period. Each candidate must normally spend at least two sequential semesters in full-time residence at Missouri S&T. The department does have special conditions for satisfying residency and meeting research requirements for full time working engineers that meet all admission standards. At appropriate points in their program, Ph.D. students must pass both a qualifying examination and a comprehensive examination. Ph.D. students must conduct original research under the supervision of a doctoral advisor, and write and successfully defend the dissertation. Some recent Ph.D. dissertation titles include:

- Development and Analysis of Intelligent Computation Based Stock Forecasting and Trading
- An Analysis of Intermodal Transportation Mode Selection Considering Stochastic System Parameters
- Surviving the Change to a Competitive Market Place in the Small Local Exchange Carrier Telecommunications Industry
- The Relationship Between R&D Spending and Shareholder Returns in High Technology Industries
- Global Stock Index Forecasting Using Multiple Generalized Regression Neural Networks with a Gating Network
- The Development of Efficient Delivery Routes in Extremely Short Product Life-Cycle Environments
- Quantification of Attribute Driven Cannibalization Induced by New Product Introduction
- Cost Allocation Using Intelligent Agents for New Transmission Investment Under Electricity Deregulation

## Residency Requirements

Students must normally spend at least two sequential semesters in full-time residence at Missouri S&T and conduct original research under the supervision of a doctoral advisor. For distance PhD students, alternative methods for meeting this residency requirement are allowed and are up to the discretion of the student's doctoral advisor, but the qualifying examination, comprehensive examination and dissertation defense must be completed on campus. The student has the option of conducting research that is beneficial to the student's professional work.

## Graduate Certificate Programs

This program is designed to appeal to working professionals. Certificate courses taken for graduate credit can be counted in the M.S. degree once accepted into the M.S. degree. If the four-course sequence is completed with a grade of "B" or better in each of the courses taken, they can apply to the M.S. program in engineering management. The certificate program may be followed by six additional 3 credit courses to complete the M.S. degree. The certificate program is open to all persons holding a B.S., M.S., or Ph.D. degree in engineering or a physical science and who have a minimum of 12-months of professional employment experience or are currently accepted into a graduate degree program at Missouri S&T.

### Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics or Chemistry, Engineering Economy
- GPA: Regular status: 2.75 cumulative
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study
- Regular status: 580/237/90

Once admitted to the program, the student must take the four designated courses as given below. In order to receive a graduate certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses.

### Engineering Management

The engineering management certificate program aims to provide individuals with a core body of engineering management knowledge that includes key technical management concepts, processes, and methods for individuals preparing to transition from individual technical contributors to managers of complex technological projects.

The certificate program coverage includes planning, organizing, allocating resources, and directing and controlling technical projects and people in technical jobs. Students will be responsible for prerequisite knowledge as determined by course instructors.

ENG MGT 5111	Management for Engineers and Scientists
ENG MGT 5320	Project Management
ENG MGT 5412	Operations Management Science
ENG MGT 6211	Advanced Financial Management

### Financial Engineering

The financial engineering certificate program aims to equip students with a set of tools that will help them meet the standards of the Global Association of Risk Professionals (GARP) and the Professional Risk Managers' International Association (PRMIA) certifications. While being separate organizations, both GARP and PRMIA have become the

standards in financial engineering and financial risk management, due to their similar knowledge of requirements for certification.

Certificate topics will help prepare students to take the GARP Financial Risk Managers (FRM) exam and/or the PRMIA Professional Risk Managers (PRM) exam. Both exams are set around topics in financial theory, financial markets and financial instruments, market risk measures, quantitative analysis, mathematical foundations of risk management, financial derivatives for risk reduction, risk management best practices, operational risk, market risk, credit risk, case studies, ethics, and governance. The certificate courses will provide a strong foundation in these areas.

Students will be responsible for prerequisite knowledge as determined by course instructors and are expected to have taken ENG MGT 5210 Economic Decision Analysis, ENG MGT 5202 Financial Decision Analysis, SYS ENG 6103 Systems Life Cycle Costing, or an equivalent introduction to finance and/or engineering economics course, as a prerequisite to the certificate program.

ENG MGT 6212	Investment
ENG MGT 6213	Financial Engineering
ENG MGT 6214	Financial Engineering II
ENG MGT 6215	Financial Risk Management

### Human Systems Integration (HSI)

This certificate will prepare students to have a significant impact on complex tasks involving humans. In our increased threat environment, the consequences of HSI failures will become even more critical. We can no longer afford to have a token human factors specialist added to teams addressing complex military issues. A more effective comprehensive approach is to broadly educate military personnel and defense contractors and others in HSI. An increased understanding of human performance will allow for improved performance across the areas of interest which will be gained from this certificate and will result in improved survivability in response to disasters and catastrophes.

The human systems integration certificate program consists of four of five courses. Students will be responsible for prerequisite knowledge as determined by course instructors. With the prior approval of the department, appropriate courses may be substituted for a certificate course if that course is not available.

ENG MGT 4330	Human Factors
ENG MGT 6001	Special Topics
IS&T 5885	Human-Computer Interaction
Select one of the following:	
ENG MGT 5316	Safety Engineering Management
IS&T 5887	Human-Computer Interaction Evaluation

### Lean Six Sigma

This certificate program offers an opportunity for professionals to expand their knowledge in Lean Six Sigma through a flexible graduate education program. The certificate provides a solid foundation of Lean Six Sigma methods and practices that can be immediately applied to process improvement projects in the work place. The certificate consists of four courses designed to prepare professionals for variation and waste reduction projects and provide a sound statistical background.

The Lean Six Sigma certificate program consists of four of the five courses below, which are delivered as part of our regular master's degree

programs in engineering management. Students will be responsible for prerequisite knowledge determined by course instructors.

ENG MGT 5710	Six Sigma
ENG MGT 6710	Design for Six Sigma
ENG MGT 6611	Lean Systems
Select one of the following:	
STAT 5643	Probability And Statistics
STAT 5353	Statistical Data Analysis

## Military Construction Management

(Certificate restricted to the Engineer Captain's Career Course at Fort Leonard Wood.)

ENG MGT 5110	Managerial Decision Making
ENG MGT 5111	Management for Engineers and Scientists
CIV ENG 5445	Construction Methods
CIV ENG 5360	Water Resources And Wastewater Engineering
or CIV ENG 6443 Contract Formulation And Project Delivery Systems	

## Project Engineering & Construction Management

Although available to all interested students, the project engineering and construction management graduate certificate program was created to specifically meet the needs of visiting faculty/graduate students from Algeria as part of the collaborative program "Development of Engineering Management Curriculum and Distance-Learning Methodologies in Algeria: An Educational Partnership," sponsored by the United States Department of State, Bureau of Educational and Cultural Affairs, and the North African Partnerships Program.

The objective of this collaborative program is to provide educational and technical assistance to Algeria in order for that country to develop new graduate programs in engineering management and construction engineering and modern teaching methodologies, including Internet and distance learning. The cooperative framework provides participants with engineering management skills and expertise to prepare them to be leaders at their home institutions.

Choose two:

CIV ENG 5445	Construction Methods
CIV ENG 5449	Engineering and Construction Contract Specifications
CIV ENG 6442	Construction Administration, Planning and Control
CIV ENG 6445	Advanced Construction Engineering

Choose two:

ENG MGT 5111	Management for Engineers and Scientists
ENG MGT 5210	Economic Decision Analysis
ENG MGT 5320	Project Management
ENG MGT 6323	Global Project Management

## Project Management

The project management certificate program aims to equip students with a set of tools that will allow them to achieve Project Management Institute (PMI) standards in the project management area, to successfully manage projects and human resources, and to analyze, evaluate, and improve systems.

The certificate program will consist of four required courses:

ENG MGT 5210	Economic Decision Analysis
ENG MGT 5320	Project Management
ENG MGT 6322	Case Studies in Project Management
ENG MGT 6323	Global Project Management

## Safety Engineering

Safe engineering systems protect the health of workers and the public, preserve the environment, and improve the profitability of industrial facilities. The graduate certificate in safety engineering is a program of study that focuses on methods to reduce risks, prevent accidents, and/or mitigate the consequences to acceptable levels. Risk reduction is accomplished by identifying hazards with unacceptable consequences and then reducing the probability of occurrence (accident reduction) and/or reducing the consequences to acceptable levels (mitigation). The program of study consists of four courses: two required core courses and two courses selected from a specialization track.

Requires two core courses and two courses selected from a track

Core Courses:		
ENG MGT 4312/	Risk Assessment and Reduction	3
CHEM ENG 5130		
ENG MGT 5316	Safety Engineering Management	3

Available Specialization Tracks:

Track 1: Chemical/Metallurgical Process Safety		
Required:		
CHEM ENG 5140		3

Choose one course from the following:

CHEM ENG 5305	Hazardous Materials Management	3
CHEM ENG 5190/	Plantwide Process Control	3
ELEC ENG 5350		
IS&T 5885	Human-Computer Interaction	3
MET ENG 5630	Environmental Aspects Of Metals Manufacturing	3

Track 2: Safety Engineering Management

ENG MGT 5713	Management And Methods In Reliability	3
SYS ENG 6110	Optimization under Uncertainty	3

Track 3: Process Control Systems

Choose two courses from the following:		
ELEC ENG 5870	Mechatronics	3
ELEC ENG 5350/	Plantwide Process Control	3
CHEM ENG 5190		
ELEC ENG 5340	Advanced PLC	3
CHEM ENG 5140		3
COMP ENG 5420	Introduction to Network Security	3

Track 4: Nuclear Process Safety

Choose two courses from the following:		
IS&T 5885	Human-Computer Interaction	3
NUC ENG 4207	Nuclear Fuel Cycle	3
NUC ENG 4229	Nuclear Power Plant Systems	3
NUC ENG 4347	Radiological Engineering	3
NUC ENG 4281	Probabilistic Risk Assessment I	3
NUC ENG 6223	Nuclear Reactor Safety	3

Track 5: Nuclear Material Safety

Required:		
NUC ENG 4312	Nuclear Radiation Measurements and Spectroscopy	3
Choose one course from the following:		
NUC ENG 4207	Nuclear Fuel Cycle	3
NUC ENG 4347	Radiological Engineering	3
NUC ENG 4363	Applied Health Physics	3
NUC ENG 6331	Radiation Shielding	3

Track 6: Radiological Health & Safety

Required:		
NUC ENG 4363	Applied Health Physics	3
Choose one course from the following:		
NUC ENG 4207	Nuclear Fuel Cycle	3
NUC ENG 4312	Nuclear Radiation Measurements and Spectroscopy	3
NUC ENG 4347	Radiological Engineering	3
NUC ENG 6331	Radiation Shielding	3

**Track 7: Human Factors**

Required:

ENG MGT 4330	Human Factors	3
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Choose one course from the following:

BIO SCI 4383	Toxicology	3
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PSYCH 4700	Industrial Psychology	3
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PSYCH 4730	Environmental Psychology	3
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**Track 8: Reliability**

Choose two courses from the following:

ENG MGT 5713	Management And Methods In Reliability	3
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STAT 5353	Statistical Data Analysis	3
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STAT 6570	Theory Of Reliability	3
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**Venkat Allada, Professor**

PHD University of Cincinnati

Sustainable produce development, product platform design, mass customization, product innovation, lean manufacturing, intelligent manufacturing systems, process planning supply chain management, systems engineering process and design.

**Casey Canfield, Assistant Professor**

PHD Carnegie Mellon University

Human Systems Integration, Human Factors, Automation, Energy Systems, Smart Cities, Organizational Behavior, Decision Science, Risk Analysis, Risk Communication, Data Visualization, Policy Analysis, Behavioral Interventions, Program Evaluation, Implementation Science, Stakeholder Engagement.

**Steven M. Corns, Associate Professor**

PHD Iowa State University

Associate Chair of Graduate Studies. Computational intelligence, Complex Systems, Bioinformatics, Infrastructure Systems Modeling, Autonomous Systems.

**Elizabeth Anne Fargher Cudney, Associate Professor**

PHD Missouri S&amp;T

Quality, Six Sigma, Robust Engineering, and Lean Enterprise.

**Cihan H Dagli, Professor**

PHD University of Birmingham, UK

Systems Architecting and Engineering, Cyber Physical Systems, Machine Learning, Deep Learning, Computational Intelligence. INCOSE Fellow, IISE, IFPR Fellow.

**David Enke, Professor**

PHD University of Missouri-Rolla

Investments, Derivatives, Options and Futures, Financial Forecasting, Trading Strategies, Hedge Funds, Endowment Investing, Financial Risk Management, Engineering Economy, Computational Finance, Computational Intelligence, Neural Networks.

**Abhijit Gosavi, Associate Professor**

PHD University of South Florida

Lean manufacturing, supply chain management, revenue management, simulation-optimization.

**Katie Grantham, Associate Professor**

PHD University of Missouri-Rolla

**Kellie Sue Grasman, Lecturer**

MBA University of Michigan Ann Arbor

**Sheryl Hodges, Assistant Teaching Professor**

DEng Louisiana Tech University

Program/Project Management, Financial Management, Organizational Management, Engineering/Construction.

**Benjamin Kwasa, Assistant Professor**

PHD Iowa State University

Organization Design in the Design of Complex Systems, Unmanned Aerial Systems Integration, Value-Driven Design, Multidisciplinary Design Optimization, Heuristic Optimization, Systems Design, Systems Engineering, Preference Formulation and Communication, Risk Simulation in Design and Modeling, Engineering Education, Meta-Modeling, Decision Analysis, Systems Requirements Development.

**Jinling Liu, Assistant Professor**

PHD The Pennsylvania State University

Artificial Intelligence, Biomedical Informatics, Precision Medicine, Big Data Analytics, Systems Biology, Immunology, Causal Inference, Multi-omics data.

**Suzanna K. Long, Professor**

PHD University of Missouri-Rolla

Department Chair. Critical Infrastructure Systems, Strategic Management, Sustainable Infrastructures, Management, Supply Chain and Transportation, Systems Management, Organizational Behavior, Sociotechnical Systems Analysis.

**Robert Marley, Robert B. Kopljar Professor**

PHD Wichita State University

Human System Integration, Ergonomics.

**Ruwen Qin, Associate Professor**

PHD Pennsylvania State University

Associate Chair for Strategic Recruitment. Real options, financial engineering, and manufacturing and service operations.

**Stephen A Raper, Associate Professor**

PHD University of Missouri-Rolla

Associate Chair of Undergraduate Studies in Engineering Management. Packaging engineering, operations, productivity, total quality management, packaging systems design, environmental aspects of packaging, and statistical process control.

**Joan Barker Schuman, Associate Teaching Professor**

PHD University of Southern Mississippi

Project Management and Engineering Economics.

**David G Spurlock, Associate Teaching Professor**

PHD University of Illinois Urbana

General Management.

**ENG MGT 5000 Special Problems (IND 0.0-6.0)**

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ENG MGT 5001 Special Topics (LEC 0.0-6.0)**

This course is designed to give the department an opportunity to test a new course. Variable title.



**ENG MGT 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Env Eng 5070, Comp Eng 5070, Elec Eng 5070, Civ Eng 5070).

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**ENG MGT 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**ENG MGT 5110 Managerial Decision Making** (LEC 3.0)

Individual and group decision making processes and principles for engineers and technical managers with emphasis on the limitations of human rationality and the roles of social influence and organizational contexts; principles and skills of negotiation. Prerequisite: Senior or graduate standing.

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**ENG MGT 5111 Management for Engineers and Scientists** (LEC 3.0)

The transition of the engineer or scientist to manager; study of management roles and theory, organizational systems and behavior, managing and motivating technical personnel, leadership, communication, processes, and customer focus. Prerequisite: Graduate standing.

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**ENG MGT 5210 Economic Decision Analysis** (LEC 3.0)

Comprehensive treatment of engineering economy including effects of taxation and inflation; sensitivity analysis; decisions with risk and uncertainty; decision trees and expected value, normally includes solutions on personal computer and student problem report. Prerequisite: Graduate students without previous course in engineering economy because of partial overlap.

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**ENG MGT 5212 Intelligent Investing** (LEC 3.0)

An overview of the essential elements of intelligent investing. Coverage includes stocks, bonds, exchange traded funds, mutual funds, stock screening, fundamental and technical analysis, valuation, market and industry analysis, macroeconomic indicators, investing strategies, and portfolio construction. Prerequisites: Senior or Graduate Standing.

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**ENG MGT 5312 Advanced Risk Assessment and Reduction** (LEC 3.0)

Safe, secure manufacturing facilities protect the health of employees and the public, preserve the environment, and increase profitability. Methods for systematically identifying hazards and estimating risk improve the safety performance and security of manufacturing facilities. Prerequisite: Senior or Graduate Standing.

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**ENG MGT 5313 Packaging Management** (LEC 3.0)

Provides a comprehensive background in the field of packaging and its place in productive systems. Emphasizes the design or economics of the system. Analyzes the management of the packaging function and interrelationship with other functions of an enterprise.

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**ENG MGT 5315 Interdisciplinary Problems In Manufacturing Automation** (LEC 1.0 and LAB 2.0)

Introduction to basic techniques and skills for concurrent engineering, manufacturing strategies, product design, process planning, manufacturing data management and communication are the topics covered. Students experiment the design process through team projects and structured manufacturing laboratory work. (Co-listed with Mech Eng 5644, Chem Eng 4310).

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**ENG MGT 5316 Safety Engineering Management** (LEC 3.0)

This course is an introduction to the principles of safety engineering applied to industrial situations. Job safety analysis, reduction of accident rates, protective equipment, safety rules and regulations, environmental hazards, health hazards, and ergonomic hazards are covered. Prerequisite: Senior or graduate standing.

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**ENG MGT 5320 Project Management** (LEC 3.0)

Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisite: Graduate Standing. (Co-listed Sys Eng 5105).

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**ENG MGT 5330 Advanced Human Factors** (LEC 3.0)

An in-depth review of the foundations of human factors, focusing on the interaction of people with various forms of technology in a variety of environments. Topics include research and evaluation methods, displays (e.g., visual, auditory), attention and information processing, decision making, motor skills, anthropometry, and biomechanics. (Co-listed with PSYCH 5710).

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**ENG MGT 5410 Industrial System Simulation** (LEC 3.0)

Simulation modeling of manufacturing and service operations through the use of computer software for operational analysis and decision making. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5411 Engineering Design Optimization** (LEC 3.0)

This course is an introduction to the theory and practice of optimal design as an element of the engineering design process. The use of optimization as a tool in the various stages of product realization and management of engineering and manufacturing activities is stressed. The course stresses the application of nonlinear programming methods. Prerequisite: Math 3304 or 3329.

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**ENG MGT 5412 Operations Management Science** (LEC 3.0)

Application of management science with an emphasis on supporting managerial decision-making. Design and operations of systems are modeled and analyzed using quantitative and qualitative techniques implemented using modern technology. Specific approaches include mathematical modeling and optimization, probabilistic/statistical analysis, and simulation. Prerequisites: Graduate standing.

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**ENG MGT 5414 Introduction To Operations Research** (LEC 3.0)

Mathematical methods for modeling and analyzing industrial systems, topics including linear programming, transportation models, and network models. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5510 Industrial Marketing Systems Analysis** (LEC 3.0)

An analysis of the factors of engineered products, customers, communication, promotion, personal selling, persuasion and management within a dynamic industrial sales environment.

Prerequisites: Senior or graduate standing.

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**ENG MGT 5511 Technical Entrepreneurship** (LEC 3.0)

Student teams develop a complete business plan for a company to develop, manufacture and distribute real technical/product service. Lectures & business fundamentals, patents, market/ technical forecasting, legal and tax aspects, venture capital, etc., by instructor and successful technical entrepreneurs. Prerequisite: Senior or graduate standing.

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**ENG MGT 5512 Legal Environment** (LEC 3.0)

Study of the effect of the legal environment on the decisions which the engineering manager must make. The course investigates the social forces that produced this environment and the responsibilities incumbent upon the engineer. Prerequisites: Senior or graduate standing.

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**ENG MGT 5513 Energy and Sustainability Management Engineering** (LEC 3.0)

This course explores strategic processes and partnership required for the management of sustainable energy infrastructures and innovation in energy systems. Topics relate to renewable energy, energy efficiencies, energy conversion, energy technology, and economic efficiency of energy sources. Prerequisite: Senior or Graduate Standing.

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**ENG MGT 5514 Patent Law** (LEC 3.0)

A presentation of the relationship between patent law and technology for students involved with developing and protecting new technology or pursuing a career in patent law. Course includes an intense study of patentability and preparation and prosecution of patent applications. Prerequisite: Senior or graduate standing.

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**ENG MGT 5515 Integrated Product And Process Design** (LEC 3.0)

Emphasize design policies of concurrent engineering and teamwork, and documenting of design process knowledge. Integration of product realization activities covering important aspects of a product life cycle such as "customer" needs analysis, concept generation, concept selection, product modeling, process development, and end of product life options. Prerequisites: Junior or above standing. (Co-listed with MECH ENG 5757).

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**ENG MGT 5516 Integrated Product Development** (LEC 1.0 and LAB 2.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, process quality, cost, supply chain management, and product support. Students will produce a final engineering product at the end of the project. Prerequisite: Eng Mgt 5515 or Mech Eng 5757 or Mech Eng 3653 or Mech Eng 5708. (Co-listed with Mech Eng 5758).

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**ENG MGT 5610 Advanced Facilities Planning & Design** (LAB 1.0 and LEC 2.0)

An integrated approach to the planning and design of facilities; examination of advanced techniques and tools for facility location, space allocation, facility layout materials handling system design, work place design; e.g. mathematical programming and simulation modeling. Prerequisites: Graduate standing.

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**ENG MGT 5613 Value Analysis** (LEC 3.0)

An organized effort at analyzing the function of goods or services for the purpose of achieving the basic functions at the lowest overall cost, consistent with achieving the essential characteristics. Covers the basic philosophy, function analysis, FAST diagramming, creativity techniques, evaluation of alternatives, criteria analysis, and value stream mapping. Prerequisite: Senior or graduate standing.

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**ENG MGT 5614 Supply Chain Management Systems** (LEC 3.0)

This course focuses on the development of logistics management skills related to global supply chains. Particular attention will be given to supply chain systems management as part of the firm's strategic positioning, cultural interactions and transportation sourcing decisions. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5615 Production Planning And Scheduling** (LEC 3.0)

Introduction to basic techniques of scheduling, manufacturing planning and control, just-in-time systems, capacity management, master production scheduling, single machine processing, constructive Algorithms for flow-shops, scheduling heuristics, intelligent scheduling systems are the topics covered. Prerequisite: Eng Mgt 3310.

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**ENG MGT 5710 Six Sigma** (LEC 3.0)

This course is an introduction to the principles of implementing the Six Sigma philosophy and methodology. Topics include tools and methods including process flow diagrams, cause and effect diagrams, failure mode and effects analysis, gage R&R, capability studies, design of experiments and strategy for organizing six sigma techniques in industry. Prerequisite: Graduate standing.

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**ENG MGT 5711 Total Quality Management** (LEC 3.0)

Examination of various quality assurance concepts and their integration into a comprehensive quality management system: statistical techniques, FMEA's, design reviews, reliability, vendor qualification, quality audits, customer relations, information systems, organizational relationships, motivation. Prerequisite: Senior or graduate standing.

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**ENG MGT 5712 Introduction To Quality Engineering** (LEC 3.0)

This course is an introduction to the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered in-depth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Other contributions in the field are also considered. Prerequisite: Eng Mgt 5711.

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**ENG MGT 5713 Management And Methods In Reliability** (LEC 3.0)

Study of basic concepts in reliability as they apply to the efficient operation of industrial systems. Prerequisite: Stat 3115, 3117, or 5643.

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**ENG MGT 5714 Statistical Process Control** (LEC 3.0)

The theoretical basis of statistical process control procedures is studied. Quantitative aspects of SPC implementation are introduced in context along with a review of Deming's principles of quality improvement and a brief introduction to sampling inspection. Prerequisite: Stat 3115, or Stat 3117.

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**ENG MGT 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**ENG MGT 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENG MGT 6010 Seminar** (IND 0.0-6.0)

Discussion of current topics.

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**ENG MGT 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**ENG MGT 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**ENG MGT 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**ENG MGT 6101 Advanced Research Methodology in Engineering Management** (LEC 3.0)

An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing. (Co-listed with Sys Eng 6101).

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**ENG MGT 6110 Case Studies In General Management** (LEC 3.0)

A quantitative study of engineering management problems related to the functioning of the industrial enterprise through case studies. Prerequisite: Preceded or accompanied by an Eng Mgt 6000 level course.

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**ENG MGT 6112 Leadership for Engineers** (LEC 3.0)

Provides engineers with a background in leadership concepts and principles; enables students to develop practical skills in leading and managing through multiple personal assessment. Topics include leadership styles, managing commitments, conflict resolution, change management, emotional intelligence, team dynamics and business ethics. Prerequisite: Eng Mgt 5110.

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**ENG MGT 6113 Advanced Personnel Management** (LEC 3.0)

Current practices of procurement and maintenance of technical personnel in research, development, and design organizations. Adaptation of such personnel to the technological enterprise, current practices in personnel administration, labor management relationships.

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**ENG MGT 6211 Advanced Financial Management** (LEC 3.0)

Principles of financial organization and management in the technological enterprise; demands for funds; internal and external supply of funds; budgetary control; reserve and dividends policy. Emphasizes systems approach and problems of engineering design and automation as they influence financial decisions. Prerequisite: Eng Mgt 1210 or 5210.

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**ENG MGT 6212 Investment** (LEC 3.0)

An introduction to the theory and practice of investment, including financial markets and instruments, security trading, mutual funds, investment banking, interest rates, risk premiums, the capital asset pricing model, arbitrage pricing theory, market efficiency, bonds and the fixed income market, equity valuation, fundamental and technical analysis. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6612).

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**ENG MGT 6213 Financial Engineering** (LEC 3.0)

An introduction to financial engineering, with an emphasis on financial derivatives, including the future markets, the pricing of forwards and futures, forward rate agreements, interest and exchange rate futures, swaps, the options markets, option strategies, the binomial and Black-Scholes models for option valuation, the option Greeks, and volatility smiles. Prerequisites: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6613).

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**ENG MGT 6214 Financial Engineering II** (LEC 3.0)

This course introduces advanced topics in financial engineering, which includes introduction to Wiener processes, martingales and Ito's lemma; basic numerical methods for options pricing, exotic options; interest rate models; stochastic volatility models and jump-diffusion models; and value-at-risk. Prerequisite: Eng Mgt 6213/Sys Eng 6613. (Co-listed with Sys Eng 6614).

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**ENG MGT 6215 Financial Risk Management** (LEC 3.0)

Techniques and methods for managing financial risk, including portfolio theory, Monte Carlo methods, ARIMA, time series forecasting, Value-at-Risk, stress testing, extreme value theory, GARCH and volatility estimation, random variables and probability distributions, real options, decision trees, utility theory, statistical decision techniques, and game theory. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6615).

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**ENG MGT 6310 Human Systems Integration** (LEC 3.0)

This course considers Human Systems Integration (HSI) in a variety of applications including systems acquisition and training, HSI tools, techniques, and procedures. Prerequisite: Eng Mgt 4330 or Psych 4710.

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**ENG MGT 6322 Case Studies in Project Management** (LEC 3.0)

Includes the main components of the Project Management Institute (PMI) Body of Knowledge; case studies in project management including project implementation, organizational structures, project estimating, project scheduling, project risk management, and conflict management. Prerequisite: Eng Mgt 5320 or equivalent.

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**ENG MGT 6323 Global Project Management** (LEC 3.0)

In depth and advanced topics in project management including project management methodologies, strategic planning for excellence, project portfolio management, integrated processes, culture, and behavioral excellence; normally includes a hands-on group project. Prerequisite: Eng Mgt 5320 or equivalent.

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**ENG MGT 6410 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Sys Eng 6217 and Comp Sci 6202).

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**ENG MGT 6411 Advanced Topics in Simulation Modeling** (LEC 3.0)

Design and analysis of distributed systems using discrete-event simulations and synchronization of distributed models. Design and implementation of finite state automata and simulation models as control execution systems. Functioning of real-time, agent-based, and multipass simulations. Prerequisite: Eng Mgt 5410 or Graduate standing.

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**ENG MGT 6412 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Math 6665 and Sys Eng 6412).

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**ENG MGT 6413 Advanced Engineering Management Science** (LEC 3.0)

Solving of managerial problems utilizing management science techniques. Problems are analyzed, modeled and solved using such techniques as linear, goal, dynamic, programming, simulation, statistical analysis or other non-linear methods. Solutions will involve the use of personal or mainframe computers. A study of the current literature in management science will also be conducted. Prerequisite: Eng Mgt 5414 or graduate standing.

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**ENG MGT 6415 Optimization under Uncertainty** (LEC 3.0)

Optimization in the presence of model uncertainty or system stochasticity is discussed. The course covers fundamentals of stochastic programming, robust optimization, and dynamic programming. Prerequisites: Graduate standing. (Co-listed with Sys Eng 6110).

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**ENG MGT 6510 Technological Innovation Management** (LEC 3.0)

Technological innovation is new technology creating new products and services. This course studies the issues of managing technological innovation under four topics: 1) Innovation; 2) New Ventures; 3) Corporate Research & 4) R&D Infrastructure. Prerequisite: Eng Mgt 5111.

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**ENG MGT 6511 Advanced Marketing Management** (LEC 3.0)

Study of marketing decision areas in the technically based firm, including product selection and development, marketing research, market development, distribution, advertising, and promotion. Pricing policies including legal aspects and problems in selecting, training and controlling field sales force. Examination of interaction within consumer and industrial marketing environments. Prerequisites: Eng Mgt 5111, Econ 1200.

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**ENG MGT 6610 Advanced Production Management** (LEC 3.0)

Examination of responsibilities of production manager in the technological enterprise for providing finished goods to meet the quality, price, quantity and specification needs of the market place. Study of functions of production manager. Quantitative approach to decision making in production management. Prerequisites: Senior or graduate standing and advanced mathematical modelling competence.

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**ENG MGT 6611 Lean Systems** (LEC 3.0)

Lean Systems embodies a total enterprise philosophy built on removing waste. Concepts such as flow, just-in-time, lead times, inventory turns, standardized work, pull system, value streams, quick changeover, workplace organization, and visual controls are discussed to improve system performance. Prerequisite: Graduate standing.

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**ENG MGT 6710 Design for Six Sigma** (LEC 3.0)

Principles of Design for Six Sigma for product development. Topics include tools and methods including quality function deployment, concept generation, concept selection, product modeling, process development, DFX strategies, failure mode and effects analysis, design of experiments, TRIZ, and robust design. Prerequisite: Eng Mgt 5710.

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**ENG MGT 6711 Quality Engineering** (LEC 3.0)

This course is an examination of the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered in depth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Prerequisites: Eng Mgt 5711 and Math 3329 or equivalent.

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**ENG MGT 6713 Tolerance Design** (LEC 3.0)

This course is an examination of the theory and practice of allowance allocation for high quality and low cost manufacture of mass-produced consumer products, including technology intensive products, such as automobiles, trucks, military and commercial airplanes, computers and consumer electronics. Prerequisite: Eng Mgt 5711 or equivalent.

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## English

The department of English and technical communication has entered into a cooperative agreement with the department of English of the University of Missouri–St. Louis to offer the master of arts in English. A maximum of 12 graduate semester hours may be taken at Missouri S&T (with no more than 9 credit hours at the 3000 level).

The program provides an avenue for place-bound secondary teachers, traditional and non-traditional Missouri S&T students, and other qualified residents of South Central Missouri to pursue advanced work whether for career advancement or for personal and lifelong learning and

enrichment. The program is also designed to help a select group of incoming freshman to complete their bachelor's and master's degrees in five years; for more information, contact the Honor Academy (master student fellowship program).

Candidates for the M.A. in English must meet the admission requirements of both the graduate schools and the departments of English at Missouri S&T and UMSL. Candidates must have a bachelor's degree, with at least 24 hours in English above the freshman level, 12 in literature courses. Normally only students with a grade point average of at least 3.0 in undergraduate English courses and an overall average of 2.75 will be considered. Applicants must submit scores for the Graduate Record Examination.

In general, students scoring below the 65th percentile on the verbal examination will not be accepted into the program. Students may retake the examination to improve their scores. In addition, the departments require letters of recommendation from two English professors with whom the student has worked. The letters, the undergraduate record, and the Graduate Record Examination scores will be the basis for the admission decision. Three emphasis areas are available: literature, composition, and creative writing. Students must submit fiction or poetry in application for the creative writing track.

Applications should be received by May 1 for fall semester and for the summer session, and December 1 for the spring semester. Late applicants will be considered but cannot be assured of admission. For more information, contact the Missouri S&T department of English and technical communication.

**Trent Alan Brown**, Professor  
PHD University of Chicago

**Eric Shane Bryan**, Associate Professor  
PHD Saint Louis University

**Anne Lucile Cotterill**, Associate Professor  
PHD Washington University

**Carleigh Davis**, Assistant Professor  
PHD East Carolina University

**Kathryn C Dolan**, Associate Professor  
PHD University of California-Santa Barbara

**Kathleen M Drowne**, Professor  
PHD University of North Carolina at Chapel Hill

**Sarah Hercula**, Assistant Professor  
PHD Illinois State University

**Ed A. Malone**, Professor  
PHD Southern Illinois University Carbondale

**Kathryn Michele Northcut**, Professor  
PHD Texas Tech University

**Daniel Charles Reardon**, Associate Professor  
PHD SUNY College at Albany

**Kristine Swenson**, Professor  
PHD University of Iowa

**Michael David Wright**, Associate Professor  
PHD Oklahoma State University Main

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**ENGLISH 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**ENGLISH 5001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENGLISH 5100 Readings In Rhetoric And Composition** (LEC 3.0)

Directed readings and writing on selected topics and areas in Rhetoric and Composition. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

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**ENGLISH 5210 Readings In British Literature** (LEC 3.0)

Directed readings and writing on selected topics and areas in British literature. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

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**ENGLISH 5220 Readings In American Literature** (LEC 3.0)

Directed readings and writing on selected topics and areas in American literature. Credit will only be given for one of English 402, 403, 404, or 405 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

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**ENGLISH 5230 Readings In Literature And Theory** (LEC 3.0)

Directed readings and writing on selected topics and areas in Literature and Theory. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

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**ENGLISH 5571 Advanced Writing For Science & Engineering** (LEC 3.0)

Focus on writing applications specifically for students in scientific or engineering fields. Primary emphases will be on producing effective and readable professional writing. Prerequisites: English 3560 and 2560, or graduate standing.

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**ENGLISH 5572 Advanced Writing For Science And Engineering II** (LEC 2.0)

This course – second in a series – focuses on writing for publication, from the initial proposal and query to the final product. Students will work on the materials they have underway with their advisers and/or research colleagues. Prerequisites: English 3560 and 2560, or graduate standing.

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## Explosives Engineering

The explosives engineering program in the department of mining and nuclear engineering offers the master of science (M.S.) and doctor of philosophy (Ph.D.) degrees and a minor and certificate in explosives engineering for students with bachelor's degrees in engineering, science or technology. It also offers an explosives technology certificate and master of science (MS) for those with other bachelor's degrees. Due to the age profile of the explosives industry and attrition of personnel, as well as the rapid change in technology within this field, there is an immediate and growing need for highly trained explosives professionals in both the civilian explosive, mining and civil excavating fields and government and the defense industry. Employers are looking for engineers and scientists with sophisticated skills in the integration

of explosives technology into complex systems in a wide range of applications. Employers are also seeking M.S. and Ph.D. graduates because they can move quickly into managerial positions.

Faculty involved in a variety of explosives related research programs teach and direct the program in conjunction with instruction by industry specialists in a wide range of applications. Students will have opportunities to assist the faculty, both in research and teaching, as well as working alongside faculty and graduate students in other engineering and science fields such as civil, architectural, mechanical, chemical, aerospace, electrical, geological, and materials engineering and geology, geophysics, chemistry and physics. The explosives engineering faculty and students will be active in the leading professional societies such as the International Society for Explosives Engineers and those in a wide range of associated areas. A security background check is required for all students in the program.

## Explosives Engineering

The M.S. program requires a minimum of 30 hours of graduate credit. A core of four courses is required of all students, and a module of allied courses in departments outside of explosives engineering is encouraged.

## Degree Requirements

**M.S. with thesis:** The M.S. degree with thesis requires the completion of 24 hours of graduate course work and six hours of research (EXP ENG 6099) and the successful completion and defense of a research thesis. Four of the following core courses are required of all M.S. students in explosives engineering:

EXP ENG 5612	Principles of Explosives Engineering
or MIN ENG 5612	Principles of Explosives Engineering
EXP ENG 5622	Blasting Design And Technology
or MIN ENG 5622	Blasting Design And Technology
EXP ENG 5713	Demolition of Buildings and Structures
MIN ENG 4922	Tunneling & Underground Construction Techniques
EXP ENG 6412	Environmental Controls For Blasting
EXP ENG 6312	Scientific Instrumentation For Explosives Testing & Blasting

Students select 12 hours of ExpE and other appropriate elective courses. M.S. in explosives engineering candidates are advised to group out-of-department courses into a module that fits their special interest.

**M.S. without thesis (by coursework):** The M.S. degree without thesis requires the completion of 30 hours of graduate coursework with the same stipulations as above. The six hours of research is replaced by course work which may include an explosives related cooperative work experience (EXP ENG 6070) or industry project (EXP ENG 6080) with an established company or government agency commonly using explosives and an additional explosives course.

## Explosives Technology Degree Requirements

The M.S. program requires a minimum of 30 hours of graduate credit. A core of four courses is required of all students, and a module of allied courses in departments outside of explosives engineering is encouraged.

**M.S. with thesis:** The M.S. degree with thesis requires the completion of 24 hours of graduate course work and six hours of research (Exp Eng 6099), and the successful completion and defense of a research thesis.

Four of the following core courses are required of all M.S. students in Explosives Technology:

EXP ENG 5612	Principles of Explosives Engineering	3
EXP ENG 5622	Blasting Design And Technology	3
EXP ENG 5711	Explosives in Industry	3
EXP ENG 5713	Demolition of Buildings and Structures	3
EXP ENG 5721	Specialty Uses of Energetic Materials	3
EXP ENG 5914	Explosives Manufacturing	3
EXP ENG 5922	Tunneling & Underground Construction Techniques	3
EXP ENG 6412	Environmental Controls For Blasting	3
EXP ENG 6312	Scientific Instrumentation For Explosives Testing & Blasting	3
EXP ENG 6112	Explosives Regulations	3

Students select 12 hours of Exp Eng and other appropriate elective courses. M.S. in explosives engineering and explosives technology candidates are advised to group out-of-department courses into a module that fits their special interest.

**M.S. without thesis (by coursework):** The M.S. degree without thesis requires the completion of 30 hours of graduate coursework with the same stipulations as above. The six hours of research is replaced by course work which may include an explosives related cooperative work experience (Exp Eng 6070) or industry project (Exp Eng 6080) with an established company or government agency commonly using explosives and an additional explosives course.

### Ph.D. Degree Requirements

The Ph.D. degree requires a minimum of 3 years of full-time study beyond the bachelor's degree, including research work for the dissertation. Minimum requirements for Ph.D. candidates include completing 72 credit hours of graduate credit with at least 24 credit hours of dissertation research (Exp Eng 6099) and a minimum of 24 credit hours of coursework, with at least 15 credit hours of course work completed at Missouri S&T. Students are encouraged to enroll in at least 15 credit hours of 6000-level lecture courses and are required to pass the qualifying, comprehensive and final oral examinations for the Ph.D. research.

## Explosives Engineering Certificate

This certificate program is designed to provide formalized education in the area of explosives engineering. Students will be exposed to the theoretical and practical approaches of explosives engineering. Students will learn analysis and design of explosive-related systems and both natural and built structure effects. The explosives engineering certificate program is open to all persons holding a B.S. (in an applied science, technology or engineering), M.S., or Ph.D. degree and who have a minimum of 12-months of post-B.S. professional employment experience. Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average cumulative grade of 3.0 or better in the certificate courses. Students admitted to the certificate program will have non-matriculated status; however, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be eligible to apply to the M.S. explosives engineering program upon application. The certificate credits taken by the student admitted to the M.S. program will count toward their master's degrees. Students who do not have all of the prerequisite courses necessary to take the course in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses. Once admitted to a certificate program, a student will be given

three years to complete the program so long as he or she maintains at least a B average in the courses taken.

The following courses are required:

EXP ENG 5612	Principles of Explosives Engineering
EXP ENG 5622	Blasting Design And Technology

Two more explosives designated classes on the approved list maintained by the explosives engineering program faculty.

3 hours of EXP ENG 6099 and EXP ENG 6000 may be substituted at the discretion of the program coordinators.

Other courses approved by the explosives engineering faculty may be substituted for any of the above listed courses on a case-by-case basis.

## Explosives Technology Certificate

This certificate program is designed to provide formalized education in the area of explosives. Students will be exposed to the theoretical and practical approaches of explosives technology. Students will learn analysis and design of explosive-related systems and both natural and built structure effects.

The following courses constitute the graduate certificate in explosives technology:

Required-One of the following four courses:

EXP ENG 5612	Principles of Explosives Engineering
EXP ENG 5711	Explosives in Industry
EXP ENG 5721	Specialty Uses of Energetic Materials
EXP ENG 5914	Explosives Manufacturing

Choose any three courses from the list below:

EXP ENG 5112	Explosives Handling and Safety
EXP ENG 5512	Commercial Pyrotechnics Operations
EXP ENG 5513	Stage Pyrotechnics and Special Effects
EXP ENG 5514	Display Fireworks Manufacturing
EXP ENG 5555	Computer Fired Pyrotechnic Show Design and Firing System Operation
EXP ENG 5622	Blasting Design And Technology
EXP ENG 5713	Demolition of Buildings and Structures
MIN ENG 5922	Tunneling & Underground Construction Techniques
EXP ENG 6112	Explosives Regulations

Other courses approved by the explosives engineering faculty may be substituted for any of the above listed courses on a case-by-case basis.

**Matthew Coy**, Lecturer  
PHD Missouri University of Science and Technology

**Stephen W Hall**, Lecturer  
MASTER Missouri University of Science and Technology

**Catherine Johnson**, Assistant Professor  
PHD University of Kentucky

**Braden Lusk**, Lecturer<sup>1</sup>  
PHD University of Missouri-Rolla

**Kyle Perry**, Associate Professor<sup>1</sup>  
PHD University of Kentucky

**Velim Petr**, Lecturer

**Matt Sutcliffe**, Lecturer

**Gillian M Worsey**, Assistant Adjunct Professor  
PHD Univeristy of Missouri-Rolla

**Paul Nicholas Worsey**, Professor Emeritus<sup>1</sup>  
PHD University of Newcastle-upon-Tyne, United Kingdom

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### **EXP ENG 5000 Special Problems** (IND 1.0-3.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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### **EXP ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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### **EXP ENG 5112 Explosives Handling and Safety** (LEC 3.0)

Basic handling & safety for explosives, explosive devices and ordnance related to laboratory handling, testing, manufacturing & storage, for both civil and defense applications. Classroom instruction only. Prerequisite: Junior Standing or above.

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### **EXP ENG 5512 Commercial Pyrotechnics Operations** (LAB 1.0 and LEC 2.0)

Provide participants with training preparing for Missouri Licensed Display Operator (Outdoor) License and advanced lead pyrotechnic operator training. Class work will be complemented by practical training in laboratory sessions, culminating in a full pyrotechnic show, from start to finish. Prerequisites: Both Chem 1310 and Chem 1319 or their equivalent; US Citizen or permanent resident, Successful background check, resident enrollment at Missouri S&T.

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### **EXP ENG 5513 Stage Pyrotechnics and Special Effects** (LAB 2.0 and LEC 1.0)

Use of energetic materials in close proximity to audiences. Provide participants with training preparing for Missouri Pyrotechnics Display Operators License. Covers: close proximity indoor and outdoor pyrotechnics and special effects. Working with stage crews and talent, safety and permitting. Prerequisites: Both Chem 1310 and Chem 1319 or their equivalent; US Citizen or permanent resident, Successful background check, resident enrollment at Missouri S&T.

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### **EXP ENG 5514 Display Fireworks Manufacturing** (LEC 1.0 and LAB 2.0)

Theory and practice of manufacturing display fireworks. Focusing on safety, chemical interaction, color development, basic theory, state and federal law. The lab will include hands on building of ball and canister shells and other pyrotechnic effects. Prerequisites: Chem 1310, Chem 1319, Chem 1100; one of Econ 1100, Econ 1200, Eng Mgt 1210; Successful background check.

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### **EXP ENG 5555 Computer Fired Pyrotechnic Show Design and Firing System Operation** (LAB 2.0 and LEC 1.0)

Students will learn to use music editing, electronic firing system operation and Fire One pyrotechnic choreography and simulation software to design their own pyromusical show programs. Creation of a musical sound track, selecting the fireworks and choreographing to the musical score. Create, setup, diagnose and fire a pyrotechnic show. Prerequisites: Exp Eng 5512 or Exp Eng 5513 and successful background check.

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**EXP ENG 5612 Principles of Explosives Engineering** (LEC 2.0 and LAB 1.0)

Theory and application of explosives in the mining industry; explosives, initiating systems, characteristics of explosive reactions and rock breakage, fundamentals of blast design, drilling and blasting, regulatory and safety considerations. Prerequisites: Min Eng 2126; successful background check. (Co-listed with Min Eng 5612).

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**EXP ENG 5622 Blasting Design And Technology** (LAB 1.0 and LEC 2.0)

Advanced theory and application of explosives in excavation; detailed underground blast design; specialized blasting including blast casting, construction and pre-splitting. Introduction to blasting research. Examination of field applications. Prerequisites: Min Eng 5612. Student must be at least 21 years of age. Successful background check. (Co-listed with Min Eng 5622).

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**EXP ENG 5711 Explosives in Industry** (LEC 3.0)

Overview of how explosives are applied in various industrial settings. Focus is placed on the general application, identification, and necessity of explosives in industry. Topics include explosive use in surface and underground mining, road development, construction, utility placement, demolition, oil, gas, and underwater.

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**EXP ENG 5713 Demolition of Buildings and Structures** (LAB 1.0 and LEC 2.0)

Provide participants with basics and solid grounding in the equipment, techniques and processes required for the demolition and remediation of mine plant and processing equipment sites and non-mining structures such as buildings, factories, bridges, etc. Field trip required. Prerequisites: Preceded or accompanied by Civ Eng 2200 or Mech Eng 2340; US citizen or permanent resident; Successful background check.

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**EXP ENG 5721 Specialty Uses of Energetic Materials** (LEC 3.0)

Overview of special, less common uses of energetic materials and how they can be applied as a functional tool. Topics include the use of energetics in aerospace, explosive ordnance, oil field development, welding, pyrotechnics, theatrics, and cinematic special effects.

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**EXP ENG 5914 Explosives Manufacturing** (LEC 3.0)

History of industrial explosives from discovery to what is used today. Manufacturing processes for packaged and bulk explosives are explored along with specialty explosives such as detonating cord, cast boosters, detonators, shaped charges, and commercial fireworks. Field manufacturing of explosives by mixing or gassing is also covered. Prerequisites: Successful background check, consent of instructor.

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**EXP ENG 5922 Tunneling & Underground Construction Techniques** (LAB 1.0 and LEC 2.0)

Mechanical and conventional excavation techniques in underground tunneling and construction. Topics include tunneling layouts design, equipment and performance modeling, ground control systems including support, drainage, and structural integrity. Construction specifications, advance rate and contractual and cost estimation. Prerequisite: Consent of instructor. (Co-listed with Min Eng 5922).

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**EXP ENG 6000 Special Problems** (IND 1.0-3.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**EXP ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**EXP ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**EXP ENG 6070 Graduate Cooperative Experience** (LAB 3.0)

Students on an approved internship will complete a project designed by the advisor and employer. The project selected must require that student apply critical thinking skills and discipline specific knowledge in the work setting. A major report and a formal presentation are required. Prerequisite: 12 hours Exp Eng coursework.

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**EXP ENG 6080 Industry Project** (LAB 3.0)

Students who are currently employed may complete a project in their work setting designed by the advisor and employer. The project selected must require that student apply critical thinking skills and discipline specific knowledge. A major report and a formal presentation are required. Prerequisite: 12 hours Exp Eng coursework.

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**EXP ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisites: Consent of instructor required.

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**EXP ENG 6112 Explosives Regulations** (LEC 3.0)

Comprehensive coverage of the federal regulations governing the explosives industry, including those governing storage of explosives (ATF), transportation of explosives (DOT and TSA), the environment (EPA) and use of explosives (OSM, MSHA and OSHA). Prerequisite: Graduate standing.

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**EXP ENG 6212 Theory Of High Explosives** (LEC 3.0)

Study of the application of chemical thermodynamics and the hydrodynamic theory to determine the properties of high explosives; application of detonation theory to steady-state detonations in real explosives; application of the above to the blasting action of explosives. Prerequisite: Graduate Standing. (Co-listed with Min Eng 6632).

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**EXP ENG 6292 Research Methods** (LEC 3.0)

Foundations, dimensions, and methods for designing and investigating research problems. Focus on fundamentals and applied research, research methods, literature review, experimental design and experimentation, dissertation composition, concepts of originality and intellectual property. Prerequisites: PhD students only. (Co-listed with Min Eng 6992).

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**EXP ENG 6312 Scientific Instrumentation For Explosives Testing & Blasting** (LEC 1.0 and LAB 2.0)

Application of scientific principles, equipment description and operation for instrumentation of explosive events including blasting. Topics: Blast chamber design, set up, high-speed photography, motion detection and measurement, explosives sensitivity testing, explosives properties testing, vibration measurement & analysis, destruction & demilitarization. Prerequisite: Exp Eng 5612 and Successful background check.

**EXP ENG 6412 Environmental Controls For Blasting** (LAB 1.0 and LEC 2.0)

Advanced blast mechanics; overbreak control including comprehensive coverage of perimeter and smoothwall specialist blasting techniques and geotechnical factors affecting blast vibration, limits analysis monitoring and control; air blast control including limits, monitoring and atmospheric and topographic effects. Prerequisites: Min Eng 5612, Successful background check. (Co-listed with Min Eng 6622).

**EXP ENG 6464 Advanced Blast Vibration Analysis and Prediction** (LEC 3.0)

Advanced Blast Vibration prediction methodologies. Includes typical methods including scaled distance, linear regression, signature hole analysis, and modern improved signature hole analysis. Structural response and damage criteria for blast vibrations including considerations for frequency spectra and amplitude. Prerequisite: Exp Eng 5612.

**EXP ENG 6767 Special Explosive Applications** (LAB 1.0 and LEC 2.0)

Advanced theory and special application of explosives other than for rock excavation. Students will be introduced to different industrial, military and government special uses such as avalanche control, explosive welding, forming, synthesis and hardening, aerospace, forest service, agriculture and oil industry applications. Prerequisites: Exp Eng 5612 or equivalent.

## Geological Engineering

Geological engineering is application of principles of geology to the solution of a wide range of problems in engineering practice, such as assessing and mitigating geologic hazards (subsidence, landslides, flooding, etc.), evaluating and improving groundwater resources, sustainably developing mineral and energy resources, selecting appropriate sites for civil and military infrastructure, and analyzing land use and environmental impacts. The graduate programs available in this multiple-industry field include:

- Graduate Certificates
- Master of Science / Master of Engineering
- Doctor of Philosophy / Doctor of Engineering

Most can be completed wholly or partially through online work. Details of these programs and their requirements are available at the departmental website and in associated sections of this catalog. Campus-wide rules for graduate degrees are repeated here only if modified; check the Graduate Studies section of this catalog for the latest updates. The catalog version in force during the semester of initial enrollment is the baseline for evaluation of graduation readiness.

Geological engineering faculty conduct research in cooperation with other MS&T departments and research centers, University of Missouri campuses, state and federal agencies, and other universities and research entities worldwide. Our laboratories and research sites are located in Missouri S&T's McNutt Hall, Rock Mechanics facility, and

Experimental Mine, as well as the Missouri Department of Natural Resources Bohigian Conservation Area and field sites both domestic and international. Some recent research projects include:

- Designing rock and soil excavating tools for use on Earth and in space.
- Measuring the permeability of soils using satellites, drones and ground-based geophysics.
- Evaluating earthquake hazards along the New Madrid fault.
- Using satellite data to investigate aquifer depletion and land subsidence.
- Studying blasting efficiency for enhancing productivity in the mining industry.
- Predicting water pollution based on geologic and land use factors.
- Developing a rock fall hazard rating system for Missouri highways.
- Assessing the effect of water saturation on rock fragmentation.
- Using LiDAR to research the rock raveling process on natural and engineered slopes.
- Developing a virtual geotechnical database for the greater St. Louis Metropolitan Area.
- Identifying areas suitable for managed aquifer recharge in the U.S. and Iraq.
- Detection of underground mines and caverns using geophysical methods.
- Using drone data to find the locations to drill wells in fractured rock.
- Modifying mining methods for use in space.
- Designing controlled methods to reduce the size of asteroids on collision courses with Earth.
- Developing sustainable point-of-use drinking water systems in developing areas.
- Using renewable energy systems to power groundwater pumping and remediation systems.
- Characterizing the reliability of renewable energy system prediction models.

## Master of Science Geological Engineering

A master's degree in geological engineering can be earned in any of several ways:

- Research Master of Science (MS), during which the student completes a research project under the direction of a graduate faculty member and writes a comprehensive thesis about the results.
- Non-thesis (also called coursework) MS. This consists of passing a selection of courses customized to serve the needs of the student.
- Master of Engineering (ME). This consists of a selective course curriculum in addition to a practice-oriented project, for which a comprehensive engineering report is written. Currently our program offers a ME degree in geotechnics that is completed online.

## Research MS in Geological Engineering

The thesis MS program consists of a minimum of 30 credit hours, including at least 21 credit hours of lecture courses (at least 9 of which must be in geological engineering), 6 or more credit hours of Geo Eng 6099 (Research), and enrollment in Geo Eng 6010 (Geological Engineering Graduate Seminar) for a minimum of two semesters.

The research topic and the course schedule are selected by the student in consultation with the advisor, who is assigned during the first semester of the student's program. The research is conducted, and the thesis is written and defended, by the student. Details of departmental and campus-wide requirements for the research MS degree can be found in the GGPE Department and Graduate Studies section of this catalog, respectively.

## Coursework MS in Geological Engineering

The non-thesis MS program consists of a minimum of 30 credit hours, including at least one course in each of the three core areas (first table below), plus one or more courses from each of the four emphasis areas following. No fewer than four courses of the total must be geological engineering courses. Course substitutions may be made on a case-by-case basis, especially if some of these courses have been completed as part of the undergraduate curriculum.

### Core Geological Engineering Courses

Take all 3 (9 credit hours).

GEO ENG 5443	Subsurface Exploration	3
GEO ENG 5331	Subsurface Hydrology	3
or GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	
GEO ENG 5441	Engineering Geology And Geotechnics	3
or GEO ENG 6441	Geotechnical Construction Practice	
or GEO ENG 6625	Applications in Geological Engineering	

### Engineering Geology and Geotechnics Emphasis Area

Choose 1-3 courses; at least one course must be in geological engineering (3 to 9 credit hours).

GEO ENG 5471	Rock Engineering	3
GEO ENG 6441	Geotechnical Construction Practice	3
GEO ENG 6477	Discontinuous Rock	3
GEO ENG 6625	Applications in Geological Engineering	3
CIV ENG 5715	Intermediate Soil Mechanics	3
CIV ENG 5716	Geotechnical Earthquake Engineering	3
CIV ENG 5729	Foundation Engineering II	3

### Environmental and Hydrology Emphasis Area

Chose 1-3 courses (3 to 9 credit hours).

GEO ENG 5233	Risk Assessment In Environmental Studies	3
GEO ENG 5235	Environmental Geological Engineering	3
GEO ENG 5237	Geological Aspects Of Hazardous Waste Management	3
GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	3
GEO ENG 6235	Advanced Concepts Of Environmental Geological Engineering	3
GEO ENG 6237	Advanced Geological & Geotechnical Design For Hazardous Waste Mgt	3
GEO ENG 6331	Advanced Subsurface Hydrology	3

### Engineering Geophysics Emphasis Area

Choose 1 to 2 courses (3 to 6 credit hours).

GEO ENG 5736	Geophysical Field Methods	3
GEO ENG 5761	Transportation Applications of Geophysics	3
GEO ENG 5782	Environmental and Engineering Geophysics	3
GEO ENG 6782	Surface Waves (MASW) and Ground Penetrating Radar (GPR)	3
GEO ENG 6784	Advanced Engineering And Environmental Geophysics	3

### Data Analysis Emphasis Area

Choose 1 to 2 courses (3 to 6 credit hours).

GEO ENG 5144	Remote Sensing Technology	3
GEO ENG 5146	Applications Of Geographic Information Systems	3
GEO ENG 5315	Advanced Statistical Methods in Geology and Engineering	3
GEO ENG 5556	Renewable Energy Systems	3
COMP SCI 5204	Regression Analysis	3
STAT 5260	Statistical Data Analysis Using SAS	3
STAT 5346	Regression Analysis	3
STAT 5353	Statistical Data Analysis	3
STAT 5814	Applied Time Series Analysis	3

## Geological Engineering-PhD

Both the PhD and DE programs consist of 90 credit hours beyond the BS degree or 60 credit hours beyond the MS degree. If these degrees are not in geological engineering or a related field, remedial courses may be required. No course below the 5000-level may be applied to the degree requirements. The schedule of course work, research, and/or engineering design is developed by the student in consultation with, and subject to the approval of, their advising committee. There is no foreign language requirement. Details of requirements for this program not covered here can be found in the Academic Program Procedures section of this catalog.

In addition to the course requirements and regardless of other degrees held, the PhD student must prepare and defend a comprehensive dissertation based on analytical, numerical, and/or experimental research on an important problem; their solution must add constructively to the body of human knowledge. A minimum of 50% of the course work credit hours and the research credit hours completed during the PhD program must be in geological engineering. Enrollment in Geo Eng 6010 (Geological Engineering Graduate Seminar) is required for four semesters.

For a student with a MS degree, 30 credit hours from the MS program are accepted toward the PhD requirement. A student holding a BS degree and pursuing the PhD directly must complete 90 total credit hours.

For the self-motivated student with access to an appropriate research project, a geological engineering PhD can be earned online. This option is designed for working professionals who do not wish to take an extended leave of absence from their posts, such as in the military, government, and research sectors.

## Geological Engineering-DE

Both the PhD and DE programs consist of 90 credit hours beyond the BS degree or 60 credit hours beyond the MS degree. If these degrees are not in geological engineering or a related field, remedial courses may be required. No course below the 5000-level may be applied to the degree requirements. The schedule of course work, research, and/or engineering design is developed by the student in consultation with, and subject to the approval of, their advising committee. There is no foreign language requirement. Details of requirements for this program not covered here can be found in the Academic Program Procedures section of this catalog.

The Doctor of Engineering (DE) program focuses on geological engineering aspects of a major engineering practice-oriented design project. A candidate for the DE must complete the equivalent of three years (six semesters) of full-time work beyond the BS degree for a total of 90 or more credit hours. In addition to formal course work, the candidate is expected to complete an internship with an industrial organization. This internship consists of a minimum of one year of planned and approved high-level engineering experience. At the end of the internship period, the student prepares an engineering design report supplemented

by appropriate research, worth 18 to 25 credit hours (included in the 90 credit hour total).

We offer several graduate certificate programs. Each consists of a four-course sequence selected according to the curricula specified below. Graduate certificate programs are available to individuals holding a BS degree in an appropriate discipline, or are currently enrolled in certain graduate degree programs at Missouri S&T. Although students in a certificate program have non-degree status, if they complete the certificate curriculum with a grade of B or better in each course, the students are eligible for admittance to selected graduate degree programs without providing GRE scores. The certificate credits taken by students who do this would then count toward those graduate degree requirements. Alternative courses may be substituted with departmental approval, depending on the availability of the courses listed. Students who do not have all prerequisites for the courses required in these programs will be permitted to take "bridge" courses as needed.

## Geoanalytics and Geointelligence

The graduate certificate in Geoanalytics and Geointelligence is designed to provide formalized education in the areas of geoanalytics, geospatial data analysis, and geointelligence.

The Geoanalytics and Geointelligence Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, Geotechnics, Civil Engineering, or similar programs or who are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Geoanalytics and Geointelligence Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to their choice of non-thesis M.S. degree programs in either Geological Engineering or Geology and Geophysics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Geoanalytics and Geointelligence Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Required Course:

GEO ENG 5144	Remote Sensing Technology	3
Three of the following courses are required:		
POL SCI 4500	Geopolitics and International Security	3
PET ENG 4111	Fundamental Digital Applications In Petroleum Engineering	3
GEO ENG 4115	Statistical Methods in Geology and Engineering <sup>1</sup>	3
or GEO ENG 5315	Advanced Statistical Methods in Geology and Engineering	
GEO ENG 5146	Applications Of Geographic Information Systems	3
GEOPHYS 5261	Computational Geophysics	3
COMP SCI 5402	Introduction to Data Mining <sup>2</sup>	3
or COMP SCI 5400	Introduction To Artificial Intelligence	
GEO ENG 5642	Military Geology	3
GEO ENG 6146	Advanced Remote Sensing And Image Processing	3
GEOLOGY 4831	Computational Geology	3

1. Only one of the listed courses may count toward completion of this certificate.

2. Only one of the listed courses may count toward completion of this certificate.

## Geoenvironmental Science and Engineering

The graduate certificate in Geoenvironmental Science and Engineering is designed to provide graduate students with the geoscience and engineering backgrounds they will need to be successful in the geoenvironmental consulting or regulatory fields.

The Geoenvironmental Science and Engineering Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, Civil Engineering, or Biology or are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Geoenvironmental Science and Engineering Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to the non-thesis M.S. degree program in Geology and Geophysics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Geoenvironmental Science and Engineering Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

One of the following courses is required:

GEOLOGY 4411	Hydrogeology	3
GEO ENG 5331	Subsurface Hydrology	3
GEO ENG 5332	Fundamentals of Groundwater Hydrology	3

Three of the following courses are required:

GEOLOGY 4431	Methods Of Karst Hydrogeology	3
GEOLOGY 4451	Aqueous Geochemistry	3
GEOPHYS 5782	Environmental and Engineering Geophysics	3
GEO ENG 5174	Geological Engineering Field Methods	3
GEO ENG 5233	Risk Assessment In Environmental Studies	3
GEO ENG 5235	Environmental Geological Engineering	3
GEO ENG 5237	Geological Aspects Of Hazardous Waste Management	3
GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	3
BIO SCI 6313	Environmental Microbiology	3
BIO SCI 6363	Advanced Freshwater Ecology	3
BIO SCI 6463	Bioremediation	3

## Geologic Hazards

The graduate certificate in Natural and Geologic Hazards is designed to provide graduate students with formalized education in the area of geologic hazards assessment and engineering.

The Geologic Hazards Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering,

Geotechnics, or Civil Engineering or who are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Geologic Hazards Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to their choice of non-thesis M.S. degree programs in either Geological Engineering or Geotechnics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Geologic Hazards Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Required Course:

GEO ENG 5441	Engineering Geology And Geotechnics	3
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One of the following courses are required:

GEO ENG 6441	Geotechnical Construction Practice	3
GEO ENG 6625	Applications in Geological Engineering	3

Two of the following courses are required:

GEO ENG 5144	Remote Sensing Technology	3
GEO ENG 5146	Applications Of Geographic Information Systems	3
CIV ENG 5337	River Mechanics And Sediment Transport	3
GEO ENG 5471	Rock Engineering	3
CIV ENG 5716	Geotechnical Earthquake Engineering	3
GEO ENG 5782	Environmental and Engineering Geophysics	3
or GEO ENG 5761	Transportation Applications of Geophysics	
GEO ENG 6146	Advanced Remote Sensing And Image Processing	3
CIV ENG 6205	Structural Dynamics and Earthquake Engineering	3
GEO ENG 6477	Discontinuous Rock	3
CIV ENG 6717	Earth Dams And Related Problems	3

## Space Resources

The graduate certificate program in Space Resources is designed to provide a pathway for non-aerospace engineering professionals to enter the emerging field of space-based resource discovery and production.

The Space Resources Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in, Geological Engineering, Geotechnics, Civil Engineering, Mining Engineering, Ceramic Engineering, Chemical Engineering, Metallurgical Engineering or Aerospace Engineering or who are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Space Resources Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to their choice of graduate degree programs in either Geological Engineering or Geotechnics. Admission to

other engineering programs will be at the discretion of those programs. The certificate credits taken by the students admitted to the graduate degree program will count towards their degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Space Resources Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

The following course is required:

GEO ENG 5810	Fundamentals of Space Resources	3
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One of the following Space Mechanics courses is required:

AERO ENG 3613	Aerospace Mechanics I	3
AERO ENG 5313	Intermediate Dynamics of Mechanical and Aerospace Systems	3

Once of the following Exploration courses is required:

GEO ENG 5144	Remote Sensing Technology	3
GEO ENG 5443	Subsurface Exploration	3
GEOLOGY 4731	Astronomy and Planetary Science	3

One of the following Processing courses is required:

CHEM ENG 4110	Chemical Engineering Process Dynamics And Control	3
CHEM ENG 5110	Intermediate Chemical Reactor Design	3
CHEM ENG 5190	Plantwide Process Control	3
MS&E 6120	Thermodynamics and Phase Equilibria	3

## Subsurface Water Resources

The graduate certificate in Subsurface Water Resources is designed to provide formalized education in the area of subsurface water resource engineering, with emphasis on groundwater extraction, protection, and remediation

The Subsurface Water Resources Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, Geotechnics, or Civil Engineering or who are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Subsurface Water Resources Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to their choice of non-thesis M.S. degree programs in either Geological Engineering or Geotechnics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Subsurface Water Resources Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Required Courses:

GEO ENG 5331	Subsurface Hydrology	3
or GEO ENG 5332	Fundamentals of Groundwater Hydrology	
or GEOLOGY 4411	Hydrogeology	

And

GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	3
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Two of the following courses are required:

GEOLOGY 4431	Methods Of Karst Hydrogeology	3
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GEOLOGY 4451	Aqueous Geochemistry	3
GEO ENG 5233	Risk Assessment In Environmental Studies	3
GEO ENG 5443	Subsurface Exploration	3
CIV ENG 5630	Remediation of Contaminated Groundwater and Soil	3
CIV ENG 5635	Phytoremediation and Natural Treatment Systems: Science and Design	3
CIV ENG 5640	Environmental Law And Regulations	3
GEO ENG 5782	Environmental and Engineering Geophysics	3
GEO ENG 6331	Advanced Subsurface Hydrology	3
GEO ENG 5235	Environmental Geological Engineering	3

**Jeffrey D Cawfield, Professor**<sup>1,2</sup>

PHD University of California-Berkeley

Director of Freshman Engineering. Probabilistic modeling and geostatistics, ground-water and contaminant transport analysis, and computer applications in geological engineering.

**Leslie Sour Gertsch, Associate Professor**

PHD Colorado School of Mines

Rock mechanics, mechanical mining and excavating, mine design and rock fragmentation.

**Katherine R Grote, Associate Professor**

PHD University of California-Berkeley

Application of geophysical techniques for hydrological site characterization with emphasis on vadose zone processes, investigation of agriculture practices for improved water management.

**Jeremy Maurer, Assistant Professor**

PHD Stanford University

Geophysics, earthquakes, induced seismicity, remote sensing, big Earth data.

**Phillip Mulligan, Assistant Research Professor**

PHD Missouri University of Science and Technology

Mining, explosives, and rock properties.

**J David Rogers, Professor**<sup>1,2</sup>

PHD University of California-Berkeley

Seismic hazards, geotechnical engineering, dam safety and earth structures.

**Taghi Sherizadeh, Assistant Professor**

PHD University of Arizona

**Ryan G Smith, Assistant Professor**

PHD Stanford University

Geophysics, remote sensing hydrology, GIS and data analytics.

**GEO ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor is required.

**GEO ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**GEO ENG 5085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**GEO ENG 5090 Geological Engineering Design** (LEC 2.0 and LAB 1.0)

Geological engineering design is an open-ended project course requiring the collection of data, analysis and synthesis of that data and design of a socially acceptable, economical solution to the selected problem. Oral and written reports are required. Prerequisite: To be taken in the semester before graduation.

**GEO ENG 5092 International Engineering and Design** (LEC 3.0)

A multi-disciplinary engineering course focused on sustainable design and technology transfer to developing countries. Course includes elements of traditional capstone design classes. Experiential learning through competitions and/or field work is a major component of the class. Prerequisites: Senior standing, instructor approval, Geo Eng 5211, Geo Eng 5247. (Co-listed with Met Eng 4510 and Cer Eng 4510).

**GEO ENG 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**GEO ENG 5144 Remote Sensing Technology** (LAB 1.0 and LEC 2.0)

Principles of digital image processing including image enhancement and multispectral classification. Emphasis upon design and implementation of remote sensing systems and analysis of remotely sensed data for geotechnical and environmental investigations. Prerequisite: Geology 1110. (Co-listed with Geology 4310).

**GEO ENG 5144H Remote Sensing Tech-H** (LAB 1.0 and LEC 2.0)**GEO ENG 5146 Applications Of Geographic Information Systems** (LEC 2.0 and LAB 1.0)

Applications of Geographical Information Systems and remote sensing to environmental monitoring, mineral resource exploration, and geotechnical site evaluation. Prerequisite: Geo Eng 3175 or consent of instructor. (Co-listed with Geology 4821).

**GEO ENG 5153 Regional Geological Engineering Problems In North America** (LEC 3.0)

A physiographic approach to engineering materials and problems. Course emphasizes the distribution and engineering characteristics of soil and rock to construction and site problems and includes aggregates, foundations, excavations, surface and ground water, slope stability and arctic conditions.

**GEO ENG 5172 Soil Science In Engineering Practice** (LEC 3.0)

A study of the ways in which soils and geologic conditions influence engineered projects. Soil formation, soil chemistry and properties to include composition, organic component, ion exchange and water relationships as well as erosion control and revegetation will be covered. Prerequisite: Geo Eng 3175.

**GEO ENG 5173 Geologic Field Methods** (LAB 3.0)

Field practice in geologic mapping and interpretation in the Western United States using topographic base maps and aerial photos. Emphasizes the description and interpretation of stratigraphic sections, sedimentary and tectonic structures. Prerequisite: Two courses in either Geology or Geological Engineering.

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**GEO ENG 5174 Geological Engineering Field Methods** (LAB 3.0)

Instruction in methods of field investigation required for geological engineering studies. Course will include procedures for qualitative and quantitative data collection for characterizing surficial geologic conditions, groundwater and surface water investigations, and other engineering activities. Written reports and field trip required.

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**GEO ENG 5211 Introduction to International Engineering and Design Lab** (LAB 1.0)

The lab for multi-disciplinary design will be as follows: Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by GEO ENG 5247.

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**GEO ENG 5233 Risk Assessment In Environmental Studies** (LEC 3.0)

This course will present the concepts required to assess the human health and environmental risks resulting from contaminants in soil and groundwater. Course topics include evaluation of data sets, exposure calculation, chemical fate and transport, and development of conceptual site models.

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**GEO ENG 5235 Environmental Geological Engineering** (LEC 3.0)

Introduction to engineering geologic mapping for site selection for solid waste disposal facilities; landfill site selection, design, permitting, construction, operation, and closeout/reclamation. Prerequisites: Geo Eng 3175, accompanied or preceded by Civ Eng 3715.

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**GEO ENG 5237 Geological Aspects Of Hazardous Waste Management** (LEC 3.0)

Nature and classification of hazardous wastes; federal and state regulation for treatment and disposal; geological characterization of facility sites; design of impoundments, storage and containment facilities; ground water monitoring and protection; site permitting and licensing planning. Prerequisite: Geo Eng 3175.

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**GEO ENG 5239 Groundwater Remediation** (LEC 3.0)

A survey of conventional and innovative techniques for remediation of contaminated groundwater. Topics include groundwater cleanup standards, physico-chemical properties of groundwater and contaminants, fate and transport of contaminants in the subsurface, hydrogeologic site characterization, and selection process of a remedial technology. Various computer programs developed to assist in preliminary selection and design of remediation technologies will be used. Prerequisite: Geo Eng 5331.

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**GEO ENG 5247 Introduction to International Engineering and Design** (LEC 2.0)

A multi-disciplinary design course focused on sustainable design and technology transfer to developing countries. Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by Geo Eng 5211.

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**GEO ENG 5276 Advanced Environmental Aspects Of Mining** (LEC 3.0)

Applied and fundamental research issues pertaining to: permitting -- the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, nonmetal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Course project. (Co-listed with Min Eng 5742).

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**GEO ENG 5315 Advanced Statistical Methods in Geology and Engineering** (LEC 3.0)

Application of statistical methods to study of geologic materials and practices, with emphasis on reliable interpretation of laboratory and field data for water, hydrocarbon, and mineral exploration, research, and engineering as well as other aspects of geological engineering. Prerequisites: Geo Eng 4115 or Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117.

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**GEO ENG 5320 Groundwater Modeling** (LEC 3.0)

This course is an introduction to advanced modeling techniques for understanding flow and transport in porous media under different hydrologic conditions. Emphasis is placed on both theoretical and practical modeling considerations. Computer demonstrations are incorporated. Practical applications are emphasized. Prerequisite: Civ Eng 3330 or Geo Eng 5331.

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**GEO ENG 5331 Subsurface Hydrology** (LAB 1.0 and LEC 2.0)

Introduction to the theory and engineering concepts of the movement of subsurface fluids. Hydraulic characteristics of earth materials, aquifer characterization, and flow prediction. Engineering problems related to subsurface fluids. Prerequisites: Geo Eng 1150 or equivalent, Math 1215.

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**GEO ENG 5332 Fundamentals of Groundwater Hydrology** (LEC 3.0)

Focus on fundamental analysis and survey of groundwater hydrology with emphasis on practical geo-environmental and subsurface hydrology issues of interest to working professionals. Topics will include general hydrology, surface and subsurface interconnection, basic groundwater flow and well test analysis, and a brief intro to contaminant transport.

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**GEO ENG 5381 Intermediate Subsurface Hydrology And Contaminant Transport Mechs** (LAB 1.0 and LEC 2.0)

A study of the physical/chemical properties of rocks and sediments in the subsurface environment. Emphasis is put on waterrock properties such as permeability, capillarity, and mechanical dispersion. Both microscopic and macroscopic approaches are used. Prerequisites: Geo Eng 5331, Geo Eng 5332, or Geol 4411.

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**GEO ENG 5415 Soil Mechanics for Geoprosessionals** (LEC 3.0)

The basic principles of soil mechanics necessary for professionals to practice in the field of geoconstruction. Topics related to the practical aspects of engineering include: soil classification, index properties, water flow through soils, compaction, compressibility, and shear strength. These basic principles will be applied to real world problems.

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**GEO ENG 5441 Engineering Geology And Geotechnics** (LEC 3.0)

Study of procedures and techniques used to evaluate geologic factors for site selection and the design of engineered structures. Prerequisite: Geo Eng 3175.

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**GEO ENG 5443 Subsurface Exploration** (LAB 1.0 and LEC 2.0)

Lectures and field and laboratory exercises in the use of geologic and geophysical techniques for evaluation of subsurface geology and resources. Prerequisite: Geo Eng 1150.

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**GEO ENG 5471 Rock Engineering** (LEC 3.0)

Data requirements for design; engineering properties of rock; characterization of fractures and rock masses; stereonet analysis of discontinuities; graphic analysis of failure; ground stress distribution; tunnel construction methods; ground support principles; selection of tunneling equipment; and specifications for underground construction. Prerequisite: Geo Eng 3175.

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**GEO ENG 5556 Renewable Energy Systems** (LEC 3.0)

Introduction to the theory and performance prediction of typical renewable energy systems such as, but not limited to, those based on energy from the sun, wind and water, and geothermal. The use of environmental data, including stochastic modeling, for renewable energy system (including wind turbine, photovoltaic, and geothermal) design is addressed. Prerequisites: Math 3304, Physics 2135, and preceded or accompanied by Geo Eng 4115 or any Probability and Statistics class. Junior or senior standing is required.

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**GEO ENG 5575 Aggregates And Quarrying** (LEC 3.0)

Properties and uses of aggregates. Finding aggregate deposits and methods of extraction. Aggregate processing. Aggregate testing. Economics and politics of aggregates. Special topics in aggregates and quarrying. Prerequisites: Geo Eng 1150, Geo Eng 3175.

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**GEO ENG 5642 Military Geology** (LEC 3.0)

This course will familiarize geologists, geophysicists, civil and geological engineers with the fundamental principles of physical geology, geohydrology and geomorphology as applied to military problems, such as development of fortifications, core infrastructure, water resources and combat engineering requirements. Prerequisite: Geo Eng 3175 or graduate standing.

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**GEO ENG 5736 Geophysical Field Methods** (LEC 2.0 and LAB 1.0)

Imaging of selected subsurface features and engineering structures using various geophysical tools. Special emphasis is placed on ground penetrating radar and surface wave techniques. One field trip at student expense required. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5736).

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**GEO ENG 5761 Transportation Applications of Geophysics** (LEC 2.0 and LAB 1.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5761 and Civ Eng 5750).

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**GEO ENG 5782 Environmental and Engineering Geophysics** (LEC 2.0 and LAB 1.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 2222. (Co-listed with Geophys 5782).

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**GEO ENG 5810 Fundamentals of Space Resources** (LEC 3.0)

Introduction to the science of the mineral resources of space, and to the engineering of extracting them for human use.

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**GEO ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEO ENG 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEO ENG 6010 Seminar** (RSD 1.0)

Discussion of current topics. Prerequisite: Graduate student.

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**GEO ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEO ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEO ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**GEO ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

**GEO ENG 6146 Advanced Remote Sensing And Image Processing** (LEC 2.0 and LAB 1.0)

Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Geo Eng 5146. (Co-listed with Geology 6341).

**GEO ENG 6235 Advanced Concepts Of Environmental Geological Engineering** (LEC 3.0)

Application of the principles of geology to the solution of engineering problems in environmental protection and remediation. Topics will include the study of geologic processes and the evaluation of geologic materials as they affect the potential for groundwater contamination, susceptibility of soils to erosion, characterization of the geologic environment for site suitability and the analysis of the criteria necessary for the selection of technologies for minimizing environmental impact. Prerequisite: Graduate level course in environmental geologic studies.

**GEO ENG 6237 Advanced Geological & Geotechnical Design For Hazardous Waste Mgt** (LEC 3.0)

Geological and geotechnical design factors for hazardous waste management facilities and remedial actions (cleanup) of uncontrolled hazardous waste sites. Prerequisite: Geo Eng 5237 or consent of instructor.

**GEO ENG 6331 Advanced Subsurface Hydrology** (LEC 3.0)

Advanced treatment of selected topics in subsurface hydrology, including groundwater contamination, contaminant transport, land disposal of wastes, aquifer test analysis, injection well technology, etc. Applied hydrogeologic site analysis and flow and transport modeling through solution of selected case examples. Prerequisite: Geo Eng 5331 or equivalent.

**GEO ENG 6332 Numerical Methods In Subsurface Flow** (LEC 3.0)

Development of governing balance equations, constitutive laws and mathematical models of groundwater flow and contaminant transport in porous media. Solution of mathematical models by finite difference and finite element methods for various boundary and initial conditions. Prerequisites: Geo Eng 5331, Comp Sci 1970.

**GEO ENG 6400 Practice Oriented Project** (IND 3.0)

This class will consist of a single term project. Students will, in consultation with the instructor, pick a topic relevant to their studies, and produce a comprehensive, in depth, professionally written report, including a literature review on the state of the practice on that topic. Prerequisites: Limited to students enrolled in the Masters of Engineering (M.E.) in Geotechnics Program.

**GEO ENG 6407 Inca Civilization Geotechnical Engineering Practices** (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Civ Eng 6760).

**GEO ENG 6441 Geotechnical Construction Practice** (LEC 3.0)

Advanced level lecture topics on procedures used for site characterization, standards for earthquake grading and construction, including embankments, building pads, retention structures, roads, levees, and earthen dams. Specific emphasis on preparation of documents involved in such work and engineer's responsibilities. Prerequisite: Geo Eng 5441.

**GEO ENG 6477 Discontinuous Rock** (LEC 3.0)

Nature and properties of discontinuous rock masses, genesis and properties of joints, role of joints in rock shear strength, slope of stability of jointed rock, fracture flow hydrogeology. Modeling of the mechanical behavior of fractured rock. Prerequisite: Min Eng 4823 or Geo Eng 5471.

**GEO ENG 6625 Applications in Geological Engineering** (LEC 3.0)

Content is focused on practical aspects of geological engineering. Geotechnical, environmental and geohydrologic case studies are presented to illustrate concepts and relate theory to applications.

**GEO ENG 6736 Advanced Geophysical Methods** (LEC 1.0 and LAB 2.0)

Geophysical field data will be acquired at selected study sites with the objective of imagine the shallow subsurface and/or built structures. Registrants will process and interpret the acquired non-invasive imaging data using ground truth as a constraint. Prerequisite: Graduate Standing.

**GEO ENG 6782 Surface Waves (MASW) and Ground Penetrating Radar (GPR)** (LAB 1.0 and LEC 2.0)

Geological engineering applications of surface wave and ground penetrating radar methods are emphasized. Field data will be acquired, processed and interpreted. Prerequisites: Geo Eng 1150 or Civ Eng 3715 or equivalent, and graduate standing.

**GEO ENG 6784 Advanced Engineering And Environmental Geophysics** (LEC 3.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential induced polarization, seismic, electromagnetic and GPR methods as applied to the solution of engineering and environmental problems. Prerequisite: Admittance into USAES-S&T Co-operative Degree Program. (Co-listed with Geophys 5251).

## Geology and Geophysics

Graduate work in geology and geophysics is offered at both the master of science (thesis and non-thesis) and doctoral levels. Programs are designed to provide you with an understanding of the fundamentals and principles of geology, geochemistry, and geophysics. Research investigations comprise a significant part of each program, and at the doctoral level an original contribution to the science is required.



Research emphasis of the program is in:

- Low Temperature and Environmental Geochemistry
- Mineralogy/Petrology/Economic Geology
- Geophysics/Tectonics/Remote Sensing
- Sedimentology/Paleontology/Stratigraphy/Petroleum Exploration

In geology and geochemistry, opportunities for research at both the M.S. and Ph.D. levels are available in mining geology, petroleum geology, environmental geochemistry, stratigraphy and sedimentation, clay mineralogy, remote sensing, GIS, palynology, structural geology, igneous and metamorphic petrology, volcanology, and planetary geology.

In geophysics, opportunities for research at both the M.S. and Ph.D. levels are available in the areas of reflection and refraction seismology, theoretical seismology, geophysical data analysis, gravity, magnetics, seismic hazards, and computational geophysics.

The study of the Earth and other planets includes all areas of scientific inquiry. To work effectively in so broad a discipline requires considerable depth and breadth of understanding of physical principles and advanced proficiency in mathematics, particularly for those students contemplating advanced studies in geophysics. A thorough undergraduate training in an earth or physical science is a prerequisite for advanced study in geology or geophysics.

Earth sciences have been an integral part of the university since its founding. The program has a long and proud history of faculty and students who have contributed to the advancement of the science, to mineral and hydrocarbon exploration, and to protecting the environment. The university was formerly the Missouri School of Mines. Because of the school's tradition and location near the Missouri Lead District, the emphasis of the program has been in exploration for mineral and petroleum resources. The program has expanded to include environmental geochemistry, geophysics, soft rock geology, and planetary geology. Our graduates find employment in the mining, petroleum, and environmental industries, as well as with government agencies and academia. The program provides students with diverse educational opportunities to prepare themselves to seek employment in any area of the earth sciences.

The program has a wide variety of equipment for research and exploration in geology, geochemistry, and geophysics. Interaction with mining engineering, geological engineering, petroleum engineering, metallurgy, environmental engineering, biological sciences and various other programs/departments is routine. Our faculty and graduate students commonly participate in collaborative research with other departments on campus as well as universities worldwide. In addition, cooperative research and internship opportunities with the Missouri Geological Survey, the U.S. Geological Survey's National Geospatial Technical Operations Center and the Mark Twain National Forest Service, all located in Rolla, are available. Cooperative programs with local mining companies, petroleum companies, or other industries are also possible. Thus, your research interests need not fall entirely within the interests of our faculty or within the bounds of the equipment directly available within the program.

A B.S. degree is essential for professional practice in geology or geophysics in industry. Due to the increasing complexity of jobs in the geosciences, the M.S. degree is recognized as the "professional degree" for geoscientists desiring employment in the Petroleum, Minerals, and many other industries. The Ph.D. degree is for those students that want to conduct original research with purpose of adding new knowledge in

a specific area of the geosciences. Successful Ph.D. candidates find employment in academia or research centers in government agencies or corporate research labs.

Two M.S. degree options are available: thesis and non-thesis. All Geology and Geophysics MS students are required to take the Professional Geosciences Skills course (GEOLOGY 5100) and either Advanced Physical Geology (GEOLOGY 5111) or Global Tectonics (GEOPHYS 5096). For students whose native language is not English, a minimum score of 79 TOEFL, or a minimum of 53 PTE, or a minimum of 6.5 IELTS is generally required for admission. Suggested minimum GRE scores: Q150 and A(W) 3.0 and (verbal score + quantitative score = 300)

All Geology and Geophysics Ph.D. students are required to take the Professional Geosciences Skills course (GEOLOGY 6100) and either Advanced Physical Geology (GEOLOGY 5111) or Global Tectonics (GEOPHYS 5096). A qualifying examination is required of all Ph.D. students during the third semester of residency.

For students whose native language is not English, a minimum score of 79 on the standard Test of English as a Foreign Language is generally required for admission. The minimum Graduate Record Examinations (GRE) scores required for acceptance consideration in the Geology and Geophysics graduate program are Q = 148, Q+V = 300, and A(W) = 3.0.

## Geoenvironmental Science and Engineering

The graduate certificate in Geoenvironmental Science and Engineering is designed to provide graduate students with the geoscience and engineering backgrounds they will need to be successful in the geoenvironmental consulting or regulatory fields.

The Geoenvironmental Science and Engineering Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, Civil Engineering, or Biology or are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Geoenvironmental Science and Engineering Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to the non-thesis M.S. degree program in Geology and Geophysics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Geoenvironmental Science and Engineering Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

### One of the following courses is required:

GEOLOGY 4411	Hydrogeology	3
GEO ENG 5331	Subsurface Hydrology	3
GEO ENG 5332	Fundamentals of Groundwater Hydrology	3

### Three of the following courses are required:

GEOLOGY 4431	Methods Of Karst Hydrogeology	3
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GEOLOGY 4451	Aqueous Geochemistry	3
GEOPHYS 5782	Environmental and Engineering Geophysics	3
GEO ENG 5174	Geological Engineering Field Methods	3
GEO ENG 5233	Risk Assessment In Environmental Studies	3
GEO ENG 5235	Environmental Geological Engineering	3
GEO ENG 5237	Geological Aspects Of Hazardous Waste Management	3
GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	3
BIO SCI 6313	Environmental Microbiology	3
BIO SCI 6363	Advanced Freshwater Ecology	3
BIO SCI 6463	Bioremediation	3

## Geophysics

The graduate certificate in Geophysics is designed to provide graduate students who want to emphasize this area of research with course guidance and a formal recognition. A certificate in Geophysics will give students an advantage when applying for careers in oil and gas, mining, and other fields.

The Geophysics Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, Petroleum Engineering, or Civil Engineering or are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Geophysics Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to the non-thesis M.S. degree program in Geology and Geophysics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Geophysics Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Four of the following courses are required:

GEOPHYS 4231	Seismic Interpretation	3
GEOPHYS 5096	Global Tectonics	3
GEOPHYS 5202	Exploration and Development Seismology	3
GEOPHYS 5211	Seismic Stratigraphy	3
GEOPHYS 5221	Wave Propagation	3
GEOPHYS 5231	Seismic Data Processing	3
GEOPHYS 5241	Advanced Electrical And Electromagnetic Methods In Geophysical Exp	3
GEOPHYS 5261	Computational Geophysics	3
GEOPHYS 5736	Geophysical Field Methods	3
GEOPHYS 5761	Transportation Applications of Geophysics	3
GEOPHYS 5782	Environmental and Engineering Geophysics	3
GEOPHYS 6211	Advanced Seismic Interpretation	3
GEOPHYS 6231	Advanced Seismic Data Processing	3
GEOPHYS 6241	The Theory of Elastic Waves	3
GEOPHYS 6251	Geophysical Inverse Theory	3
GEO ENG 6782	Surface Waves (MASW) and Ground Penetrating Radar (GPR)	3

## Petroleum Systems

The graduate certificate in Petroleum Systems is designed to provide graduate students in the geosciences, geological engineering, and petroleum engineering with the key interdisciplinary backgrounds they will need to be successful in the oil and gas industry.

The Petroleum Systems Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Geology, Geophysics, Geological Engineering, or Petroleum Engineering or are currently accepted into a graduate degree program in one of these fields at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Petroleum Systems Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to the non-thesis M.S. degree program in Geology and Geophysics. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Petroleum Systems Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Required Courses:

GEOLOGY 5513	Petroleum Geology	3
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One of the following Geophysics courses:

GEOPHYS 4231	Seismic Interpretation	3
GEOPHYS 5202	Exploration and Development Seismology	3
GEOPHYS 5211	Seismic Stratigraphy	3
GEOPHYS 5231	Seismic Data Processing	3
GEOPHYS 5261	Computational Geophysics	3

One of the following Geology courses:

GEOLOGY 5311	Depositional Systems	3
GEOLOGY 5511	Applied Petroleum Geology	3
GEOLOGY 5631	Carbonate Petrology	3
GEOLOGY 5661	Advanced Stratigraphy and Basin Evolution	3
GEOLOGY 5671	Clay Mineralogy	3
GEOLOGY 5741	Micropaleontology	3
GEOLOGY 6311	Advanced Structural Geology	3
GEOLOGY 6321	Analytical Structural Geology	3
GEOLOGY 6511	Advanced Petroleum Geology	3
GEOLOGY 6621	Clastic Sedimentary Petrology	3
GEOLOGY 6811	Sedimentary Basin Analysis	3

One of the following Petroleum Engineering courses:

PET ENG 4111	Fundamental Digital Applications In Petroleum Engineering	3
PET ENG 4210	Drilling and Well Design	3
PET ENG 4311	Reservoir Characterization	3
PET ENG 4590	Petroleum Economics and Asset Valuation	3
PET ENG 4720	Mechanical Earth Modeling	3
PET ENG 6711	Geodynamics	3

**David M. Borrok**, Professor

PHD University of Notre Dame

Aqueous geochemistry, petroleum geochemistry, water resources.

**Andreas Eckert**, Associate Professor  
PHD University of Karlsruhe  
Mechanical earth modeling, finite element methods in petroleum engineering, petroleum geomechanics and geophysics.

**Stephen Shangxing Gao**, Professor  
PHD University of California-Los Angeles  
Seismology, solid earth geophysics, crustal deformation, computational geophysics, plate tectonics.

**John Patrick Hogan**, Associate Professor  
PHD Virginia Polytechnic Institute  
Igneous petrology, structural geology, crust and mantle evolution.

**Kelly Hong Liu**, Professor  
PHD University of California-Los Angeles  
Exploration geophysics, digital signal processing, seismic hazard, earth structure and dynamics.

**Marek Locmelis**, Assistant Professor  
PHD Marquarie University, Sydney

**Jeremy Maurer**, Assistant Professor  
PHD Stanford University  
Geophysics, earthquakes, induced seismicity, remote sensing, big Earth data.

**Francisca Oboh Ikuenobe**, Professor<sup>2</sup>  
PHD Cambridge University  
Palynology, biostratigraphy, sedimentology, paleoclimatology.

**Jonathan Obrist Farmer**, Assistant Professor  
PHD Missouri University of Science and Technology

**Ryan G Smith**, Assistant Professor  
PHD Stanford University  
Geophysics, remote sensing hydrology, GIS and data analytics.

**David J Wronkiewicz**, Associate Professor  
PHD New Mexico Institute of Mining & Technology

**Wan Yang**, Associate Professor  
PHD University of Texas at Austin  
Sedimentology, sequence stratigraphy, petroleum geology, paleoclimatology.

**GEOLOGY 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEOLOGY 5001 Special Topics** (LAB 0.0 and LEC 0.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEOLOGY 5010 Seminar** (LEC 0.50)  
Discussion of current topics.

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**GEOLOGY 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEOLOGY 5085 Internship** (IND 3.0)

Students will select, with their committee's advice, problems for investigation and preparation of a graduate research proposal. Problems must provide higher level experiential learning consistent with a graduate degree in geology. Assessment is based upon the quality of written and oral presentations and supervisor's evaluation. Repeatable for credit. Prerequisite: Graduate Standing.

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**GEOLOGY 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

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**GEOLOGY 5100 Professional Geoscience Skills** (LEC 3.0)

Development and communication of complex topics in the geosciences is required for successful post-MS career advancement. Best practices for developing these skills in the geosciences will be critiqued weekly, culminating with poster and oral presentations. Assessment by peer-review and self-evaluation. Topics selected from geosciences careers. Prerequisites: Graduate Standing.

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**GEOLOGY 5111 Advanced Physical Geology** (LEC 3.0)

Examination of topics concerned with the physical properties of earth materials, processes affecting change of the surface and interior of the earth, and the driving forces causing these changes. Weekly critical assessment of literature, and an oral presentation and term paper required. Prerequisite: Consent of instructor.

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**GEOLOGY 5121 Advanced Historical Geology** (LEC 2.0 and LAB 1.0)

Study of the physical and biological history of the Earth beginning with the origin of the solar system up to the present. Emphasis will be placed on processes that shaped the Earth and its ecosystems. Prerequisite: Entrance requirements for the MST program in Earth Science.

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**GEOLOGY 5311 Depositional Systems** (LEC 3.0)

Development of three dimensional depositional models using Walther's Law, Walther's Warning and seismic stratigraphy. Emphasis on overall geometries and internal porosity and permeability characteristics of aquifers and hydrocarbon reservoirs. Includes 3-D models for clastic, carbonate and evaporate sequences. Prerequisites: Geology 1110 or Geo Eng 1150; accompanied or preceded by both Geology 3310 and Geology 3620.

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**GEOLOGY 5511 Applied Petroleum Geology** (LAB 2.0 and LEC 1.0)

The principles of petroleum geology are applied in solving hydrocarbon exploration and developmental problems. Geological and economical techniques for evaluating hydrocarbonbearing reservoirs are presented, with methods for decisionmaking under conditions of extreme uncertainty. Prerequisite: Consent of instructor.

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**GEOLOGY 5513 Petroleum Geology** (LAB 1.0 and LEC 2.0)

Principles of origin, migration, and accumulation of oil and gas. The laboratory introduces the procedures used for exploration, and development of hydrocarbon resources. Prerequisites: Geology 1110 or Geo Eng 1150; accompanied or preceded by both Geology 3310 and Geology 3620.

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**GEOLOGY 5521 Coal Petrology** (LEC 3.0)

Formation, composition, and properties of coals. Discussion of the geology of selected coal deposits, the analysis of coal, and the optical identification of coal minerals. Prerequisite: Permission of instructor.

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**GEOLOGY 5611 Granites And Rhyolites** (LAB 1.0 and LEC 3.0)

Processes governing the generation and crystallization of felsic magma will be covered, with specific reference to: 1) crust vs mantle sources, 2) melt migration and emplacement, 3) magma chamber dynamics, 4) the volcanic-plutonic connection, and 5) the relationship to tectonic setting. A field trip at the student's expense is required. Prerequisite: Geology 2620.

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**GEOLOGY 5631 Carbonate Petrology** (LEC 2.0 and LAB 1.0)

Petrology, chemistry and sedimentology of carbonates and other associated chemical sedimentary rocks. Prerequisites: GEOLOGY 2620, 3620 and CHEM 1320 or equivalent; GEOLOGY 3410 recommended.

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**GEOLOGY 5641 Advanced Igneous Petrology** (LEC 2.0 and LAB 1.0)

The genesis of eruptive rocks as evidenced by the physico-chemical conditions of formation of their constituent minerals. A critical examination of various magmatic processes. Use of advanced petrographic techniques. Prerequisites: GEOLOGY 4631.

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**GEOLOGY 5661 Advanced Stratigraphy and Basin Evolution** (LEC 3.0)

Advanced topics in sedimentary geology including: tectonic controls on sedimentary basin development, global sequence stratigraphy, regional facies and diagenetic patterns, basin hydrogeology, thermal evolution of basins and distribution of economic resources. This course should be preceded or accompanied by Geology 3410. Prerequisites: Geology 3620 and Geology 3310.

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**GEOLOGY 5671 Clay Mineralogy** (LAB 1.0 and LEC 2.0)

Mineral structure, geochemical properties, occurrence, environment, and uses of clays. Determination of physical properties, optics, x-ray diffraction, and thermal features of clays. Field trip fee required. Prerequisites: Geology 2610 and 3410, or Chem 2310, or Civ Eng 5715, or Geo Eng 5172.

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**GEOLOGY 5679 Field and Laboratory Studies in Earth Science** (LAB 3.0)

Hands-on laboratory and field experiences in the Earth Sciences. This course is designed to be taught in an intensive three week session during the summer on the S&T campus. Prerequisites: GEOLOGY 2096 or 5121 or equivalents.

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**GEOLOGY 5681 Lidar Principles and Application** (LEC 3.0)

Provides a comprehensive understanding of light detection and ranging (lidar) technology as it has been developed for commercial use; various methods of deploying technology for collection of data for mapping, engineering and science, and application of the data using specialized software for editing and processing point cloud data. Assumes GIS experience. Prerequisite: Senior or graduate standing.

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**GEOLOGY 5741 Micropaleontology** (LEC 2.0 and LAB 1.0)

This course studies the fossil and soft-body characteristics of bacteria, protists, microinvertebrates and organic-walled microfossils (palynomorphs). Focused discussions on systematics, evolutionary histories, paleoecology, and geologic applications of the microfossil groups. Extraction of foraminifera and palynomorphs from rocks in lab. Prerequisite: Geology 4630.

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**GEOLOGY 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEOLOGY 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEOLOGY 6010 Seminar** (IND 0.0-6.0)

Discussion of current topics.

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**GEOLOGY 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEOLOGY 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEOLOGY 6085 Internship** (IND 3.0)

Students will select, with their committee's advice, problems for investigation and preparation of a graduate research proposal. Problems must provide higher level experiential learning consistent with a graduate degree in geology. Assessment is based upon the quality of written and oral presentations and supervisor's evaluation. Repeatable for credit. Prerequisite: Graduate standing.

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**GEOLOGY 6097 Advanced Geologic Field Methods** (LEC 3.0)

Advanced instruction in planning and implementation of geologic field campaigns, development of an appropriate scientific plan, including logistics, safety, and supervision of field personnel in a manner consistent with professional practices. Emphasis placed upon reflection on projects outcomes supervised with faculty oversight. Field Trip fee required.

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**GEOLOGY 6098 Advanced Geologic Field Methods** (LEC 3.0)

Adv. instruction in theory and practice of qualitative/quantitative description of spatial relationships of rock types in areas exhibiting complex deformation. Emphasis on expl. learning where students plan, implement, and reflect on outcomes for sev. scientific field campaigns in a manner consistent with prof. scientific practices. Field trip fee required.

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**GEOLOGY 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

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**GEOLOGY 6100 Advanced Professional Geoscience Skills** (LEC 3.0)

Communication of complex research topics in the geosciences is required for successful post-doctoral career advancement in both academic and non-academic career paths. Best practices for developing and proposing scientific ideas in the geosciences will be critiqued weekly. Assessment of research proposals presentations includes peer-and self-evaluation. Prerequisites: Doctoral Graduate Standing.

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**GEOLOGY 6211 Geodynamics** (LEC 3.0)

The applications of continuum physics to geological and petroleum engineering problems. Topics include plate tectonics, stress and strain in solids, elasticity and flexure, heat transfer, gravity, fluid mechanics, rock rheology, faulting, and flow in porous media. Prerequisites: Math 2222 and Geology 3310. (Co-listed with Pet Eng 6711).

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**GEOLOGY 6311 Advanced Structural Geology** (LAB 1.0 and LEC 2.0)

The course provides theoretical background, analytical techniques, and hands-on experience for analyzing geologic structures at a variety of scales hand sample to global. Prerequisites: Geology 3310, Geophys 4096.

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**GEOLOGY 6321 Analytical Structural Geology** (LAB 1.0 and LEC 2.0)

The course provides theoretical background, analytical techniques, and hands-on experience, for quantifying processes that lead to the formation and evolution of rocks and structures produced as a result of deformation at a variety of scales - hand sample to global. Poster - and oral - presentations, and a research paper required. Prerequisites: Geology 3310, Geophys 4096.

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**GEOLOGY 6331 Geotectonics** (LEC 3.0)

A critical study of the origin, and differentiation of the earth, evolution of the crust, and plate tectonics. Geology of the continents and ocean basins. Regional tectonic analysis of precambrian shields, platforms, orogenic belts, and a review of internal energy sources. Emphasis is on North America. Prerequisite: Geology 3310.

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**GEOLOGY 6341 Advanced Remote Sensing And Image Processing** (LEC 2.0 and LAB 1.0)

Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Geo Eng 5146. (Co-listed with Geo Eng 6146).

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**GEOLOGY 6351 Advanced Geochemistry** (LEC 3.0)

A study of the absolute and relative abundance of elements and isotopes in the Earth, principles of element transport, formation of the Earth's crust, mineral deposits, and soils. Field trip fee required. Prerequisite: Geology 3410.

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**GEOLOGY 6411 Advanced Isotope Geochemistry** (LEC 2.0 and LAB 1.0)

The use of radiogenic and stable isotopes in geology in the study of the evolution of Earth, crust, mantle, and the Solar System as well as applications to geothermometry, ore petrogenesis, paleontology, and the global climate system. Prerequisites: Geology 2620, 3620, 3410.

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**GEOLOGY 6421 Environmental Geology** (LEC 3.0)

Overview of environmental problems facing humans. Emphasis will be placed on surface and groundwater pollution, geological hazards, and pressures on Earth's ecosystems and natural resources by urbanization and population growth. Prerequisites: GEOLOGY 1110 or 1120 or equivalents.

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**GEOLOGY 6511 Advanced Petroleum Geology** (LEC 1.0 and LAB 2.0)

The principles of petroleum geology are applied in solving hydrocarbon exploration and developmental problems. Various types of oil and gas accumulations are reviewed in detail. Study of criteria useful in evaluating the petroleum potential of undrilled areas. Special investigation assignment is required. Prerequisite: Geology 3310, Geology 5513, Geology 5661, or Geology 6811.

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**GEOLOGY 6521 Advanced Ore Microscopy** (LEC 1.0 and LAB 2.0)

A study of ore suites utilizing various advanced, quantitative ore microscopy techniques including hardness, spectral reflectance, indentation, color, rotation property measurements, fluid inclusion geothermometry, and salinity measurements. Laboratory study includes demonstration and operation of the luminescope and other microbeam techniques. Prerequisite: Geology 4521.

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**GEOLOGY 6531 Applied Ore Microscopy** (LAB 2.0 and LEC 1.0)

Application of ore microscopic and petrographic techniques to problems in ore beneficiation, pelleting, sintering, smelting, refining, refractories, cement, mining, and exploration. Discussions and laboratories are based upon industrial case histories. Prerequisite: Geology 4521.

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**GEOLOGY 6541 Geology of Natural Resources** (LEC 3.0)

The origin and distribution of economically important natural resources including soils, water resources, metals, non-metals, building materials, petroleum, and other energy resources. Prerequisites: GEOLOGY 1110 or 1120 or equivalents.

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**GEOLOGY 6551 Ore Deposition** (LAB 1.0 and LEC 2.0)

An advanced study of mineral deposits, time and space in deposition, theories of deposition and their effect on exploration. Discussions based on maps, logs, and samples from the world's typical mineral deposits. Two all day field trips at student expense required. Prerequisite: Geology 3511.

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**GEOLOGY 6611 Advanced Palynology** (LEC 1.0 and LAB 2.0)

Study of organic-walled microfossils, and the processes of sporopollenin preservation, sedimentation and palynofacies. Chronicle of Phanerozoic palynology in lectures. Major emphasis on independent palynostratigraphic research and applications, such as biostratigraphy, paleoclimatology and paleoenvironments. Prerequisite: Geology 3631 or Geology 5741.

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**GEOLOGY 6621 Clastic Sedimentary Petrology** (LAB 1.0 and LEC 2.0)

Petrology and petrography of clastic sedimentary rocks. Emphasis on origin, diagenesis and description of clastic, sedimentary rocks. Prerequisite: Geology 3620.

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**GEOLOGY 6651 Granite and Rhyolite Petrogenesis** (LAB 1.0 and LEC 3.0)

The origin of granites and rhyolites with respect to extreme fractionation, crustal anatexis, magma mixing, and tectonic setting will be explored through critical reading of the literature and examination of hand samples and thin sections from classic geologic terranes. A research paper is required as well as a field trip at the student's expense. Prerequisite: Geology 2620.

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**GEOLOGY 6711 Advanced Paleoclimatology and Paleoecology** (LEC 3.0)

Advanced study of paleoclimatic and paleoecologic processes since the Archean, and the interpretation of Holocene climate changes, including human impacts. Extensive presentations and discussions of current ideas and techniques in paleoclimatic studies. Prerequisite: Geology 3620.

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**GEOLOGY 6811 Sedimentary Basin Analysis** (LEC 3.0)

An advanced study of stratigraphic, diagenetic and tectonic processes in sedimentary basins. Prerequisites: Geology 3310, 3620, 3410 or 4441 or 4451.

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**GEOPHYS 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEOPHYS 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEOPHYS 5010 Seminar** (LEC 0.50)

Discussion of current topics.

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**GEOPHYS 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEOPHYS 5096 Global Tectonics** (LEC 3.0)

An integrated view of the Earth's structure and dynamics with an emphasis on information gained through geophysical methods. Topics include seismology, heat flow, gravity, rheological and compositional structure, plate motions and intermotions, and mantle driving mechanisms for plate tectonics. Prerequisite: Geology 3310.

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**GEOPHYS 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**GEOPHYS 5202 Exploration and Development Seismology** (LEC 2.0 and LAB 1.0)

Principles of reflection seismology as applied to the delineation of geologic structures and the determination of stratigraphy and lithology. Emphasis on both the capabilities and limitations of the seismic method. The laboratory utilizes both modeled and actual seismic data. Prerequisites: Math 1208 or Math 1214; Geology 1110 or Geo Eng 1150.

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**GEOPHYS 5211 Seismic Stratigraphy** (LEC 2.0 and LAB 1.0)

A study of the seismic expression of depositional models. Reflection patterns and reflection amplitudes are interpreted to determine bed thicknesses, fluid content, depositional environment, and lithology. Special data acquisition and processing techniques are examined. Prerequisites: Geophys 4521, Geology 3310, 3620.

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**GEOPHYS 5221 Wave Propagation** (LEC 3.0)

A study of Hamilton's principle and energy theorems, fundamentals of plane wave theory, waves in stratified fluids, elastic waves in solids, electromagnetic and hydromagnetic radiation, and Allen's functions and point sources. Prerequisites: Geophys 281, 3221.

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**GEOPHYS 5231 Seismic Data Processing** (LEC 2.0 and LAB 1.0)

Introduction to seismic data processing. Topics to be covered include statics corrections, filtering, velocity analysis, deconvolution, stacking and migration. The course has a field component to record seismic data. If this is offered in the summer, an off-campus trip may be needed. Extra fee may be charged to cover the field expenses. Prerequisites: Geophys 3210 or Geophys 5202.

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**GEOPHYS 5241 Advanced Electrical And Electromagnetic Methods In Geophysical Exp** (LAB 1.0 and LEC 2.0)

Theory of the electrical geophysical methods as applied to subsurface investigations addressing geologic, engineering, groundwater and contaminant transport problems. Course content includes both passive and active methods and recent advances in the application of these methods. Course will include a field component illustrating application of techniques to local problems. Prerequisites: Geophys 3251, Math 2222.

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**GEOPHYS 5261 Computational Geophysics** (LAB 2.0 and LEC 1.0)

Scientific programming in a UNIX/Linux environment, with emphasis on solving geophysical problems such as linear and nonlinear inversion, spectral analysis, seismicity, seismic wave attenuation, shear-wave splitting, and seismic tomography. Prerequisite: Geophys 3210.

**GEOPHYS 5736 Geophysical Field Methods** (LEC 2.0 and LAB 1.0)

Imaging of selected subsurface features and engineering structures using various geophysical tools. Special emphasis is placed on ground penetrating radar and surface wave techniques. One field trip at student expense required. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5736).

**GEOPHYS 5761 Transportation Applications of Geophysics** (LAB 1.0 and LEC 2.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5761 and Civ Eng 5750).

**GEOPHYS 5782 Environmental and Engineering Geophysics** (LAB 1.0 and LEC 2.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 2222. (Co-listed with Geo Eng 5782).

**GEOPHYS 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**GEOPHYS 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**GEOPHYS 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**GEOPHYS 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**GEOPHYS 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**GEOPHYS 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**GEOPHYS 6211 Advanced Seismic Interpretation** (LAB 1.0 and LEC 2.0)

The integration of geologic information, well log data and seismic information for interpreting the earth's subsurface using advanced 3-D seismic interpretation software packages. Reservoir identification and evaluation as well as horizon and formation attributes are included. Prerequisites: Geophys 3210 or Geophys 5202.

**GEOPHYS 6231 Advanced Seismic Data Processing** (LEC 2.0 and LAB 1.0)

Theory and application of seismic data processing. Topics to be covered include convolution, correlation, deconvolution, 2-D filtering, migration and inversion. Prerequisites: Geophys 5202, 5231, Stat 3115.

**GEOPHYS 6241 The Theory of Elastic Waves** (LAB 1.0 and LEC 2.0)

A mathematical study of elastic waves in the layered earth. Prerequisites: Geophys 3210.

**GEOPHYS 6251 Geophysical Inverse Theory** (LAB 1.0 and LEC 2.0)

A study of inverse theory applied to geophysical data, focusing on the relationship between data and model spaces and ways to estimate model parameters via global and local optimization techniques. Prerequisites: Geophys 3210 or Graduate Standing in GGPE.

## Geotechnics

The geological engineering program at Missouri University of Science and Technology offers an on-line masters of engineering degree in geotechnics. This web-based degree is designed for working professions, whose upward mobility requires an advanced degree, but who do not wish to take an extended leave of absence to physically attend college. The program is an interdisciplinary master's degree program without a required research component. Courses in geological, civil, and mining engineering can be applied to the degree. The program is offered using distance-education methods and therefore there is no formal residency requirement.

## Entrance Requirements

This program is open to graduates holding a B.S. degree in engineering or geology or other hard sciences. (For graduates of a non-engineering B.S. some bridging courses may be required). Prerequisite requirements include at least one introductory course in physical geology and one introductory course in rock mechanics or soil mechanics or equivalent. Effective through the academic year 2019, the minimum GRE scores required are Q=148, Q+V=300, and A(W)=3.0. Beginning with the 2020 academic year, the minimum GRE scores required are Q=150, Q+V=300, and A(W)=3.0. No GRE score is required if students first completed the four-course program in geotechnics. For international students, minimum English testing scores are TOEFL 79, or IELTS 6.5, or PTE 53.

Contact information e-mail [gtech@mst.edu](mailto:gtech@mst.edu) or visit our website at <http://gtech.mst.edu/>.

## Course Requirements

This web-based degree is designed for working professionals whose upward mobility requires an advanced degree, but who do not wish to take an extended leave of absence to physically attend college. It

requires 30 credit hours of graduate credit in 4000, 5000, and 6000 level courses, and a practice-oriented report instead of a research project. The following four core courses (12 credit hours) are mandatory:

GEO ENG 5381	Intermediate Subsurface Hydrology And Contaminant Transport Mechs	3
GEO ENG 5441	Engineering Geology And Geotechnics	3
GEO ENG 5471	Rock Engineering	3
GEO ENG 6400	Practice Oriented Project	3
CIV ENG 5715	Intermediate Soil Mechanics	3

Of the additional 15 credit hours of course work, up to 9 credit hours of graduate credit (minimum grade B) can be transferred from another university with advisor approval if not used toward another degree. The balance of the credit hours must be Missouri S&T graduate courses. At least 15 credit hours must be geological engineering courses, and at least 9 credit hours must be from 6000-level courses.

**Jeffrey D Cawfield**, Professor<sup>1,2</sup>

PHD University of California-Berkeley  
Director of Freshman Engineering. Probabilistic modeling and geostatistics, ground-water and contaminant transport analysis, and computer applications in geological engineering.

**Leslie Sour Gertsch**, Associate Professor

PHD Colorado School of Mines  
Rock mechanics, mechanical mining and excavating, mine design and rock fragmentation.

**Katherine R Grote**, Associate Professor

PHD University of California-Berkeley  
Application of geophysical techniques for hydrological site characterization with emphasis on vadose zone processes, investigation of agriculture practices for improved water management.

**Jeremy Maurer**, Assistant Professor

PHD Stanford University  
Geophysics, earthquakes, induced seismicity, remote sensing, big Earth data.

**Phillip Mulligan**, Assistant Research Professor

PHD Missouri University of Science and Technology  
Mining, explosives, and rock properties.

**J David Rogers**, Professor<sup>1,2</sup>

PHD University of California-Berkeley  
Seismic hazards, geotechnical engineering, dam safety and earth structures.

**Taghi Sherizadeh**, Assistant Professor

PHD University of Arizona  
Computational mechanics, numerical, statistical, and probabilistic modeling in rock mechanics.

**Ryan G Smith**, Assistant Professor

PHD Stanford University  
Geophysics, remote sensing hydrology, GIS and data analytics.

**GEO ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor is required.

**GEO ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**GEO ENG 5085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**GEO ENG 5090 Geological Engineering Design** (LEC 2.0 and LAB 1.0)

Geological engineering design is an open-ended project course requiring the collection of data, analysis and synthesis of that data and design of a socially acceptable, economical solution to the selected problem. Oral and written reports are required. Prerequisite: To be taken in the semester before graduation.

**GEO ENG 5092 International Engineering and Design** (LEC 3.0)

A multi-disciplinary engineering course focused on sustainable design and technology transfer to developing countries. Course includes elements of traditional capstone design classes. Experiential learning through competitions and/or field work is a major component of the class. Prerequisites: Senior standing, instructor approval, Geo Eng 5211, Geo Eng 5247. (Co-listed with Met Eng 4510 and Cer Eng 4510).

**GEO ENG 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**GEO ENG 5144 Remote Sensing Technology** (LAB 1.0 and LEC 2.0)

Principles of digital image processing including image enhancement and multispectral classification. Emphasis upon design and implementation of remote sensing systems and analysis of remotely sensed data for geotechnical and environmental investigations. Prerequisite: Geology 1110. (Co-listed with Geology 4310).

**GEO ENG 5144H Remote Sensing Tech-H** (LAB 1.0 and LEC 2.0)

**GEO ENG 5146 Applications Of Geographic Information Systems** (LEC 2.0 and LAB 1.0)

Applications of Geographical Information Systems and remote sensing to environmental monitoring, mineral resource exploration, and geotechnical site evaluation. Prerequisite: Geo Eng 3175 or consent of instructor. (Co-listed with Geology 4821).

**GEO ENG 5153 Regional Geological Engineering Problems In North America** (LEC 3.0)

A physiographic approach to engineering materials and problems. Course emphasizes the distribution and engineering characteristics of soil and rock to construction and site problems and includes aggregates, foundations, excavations, surface and ground water, slope stability and arctic conditions.



**GEO ENG 5172 Soil Science In Engineering Practice** (LEC 3.0)

A study of the ways in which soils and geologic conditions influence engineered projects. Soil formation, soil chemistry and properties to include composition, organic component, ion exchange and water relationships as well as erosion control and revegetation will be covered. Prerequisite: Geo Eng 3175.

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**GEO ENG 5173 Geologic Field Methods** (LAB 3.0)

Field practice in geologic mapping and interpretation in the Western United States using topographic base maps and aerial photos. Emphasizes the description and interpretation of stratigraphic sections, sedimentary and tectonic structures. Prerequisite: Two courses in either Geology or Geological Engineering.

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**GEO ENG 5174 Geological Engineering Field Methods** (LAB 3.0)

Instruction in methods of field investigation required for geological engineering studies. Course will include procedures for qualitative and quantitative data collection for characterizing surficial geologic conditions, groundwater and surface water investigations, and other engineering activities. Written reports and field trip required.

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**GEO ENG 5211 Introduction to International Engineering and Design Lab** (LAB 1.0)

The lab for multi-disciplinary design will be as follows: Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by GEO ENG 5247.

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**GEO ENG 5233 Risk Assessment In Environmental Studies** (LEC 3.0)

This course will present the concepts required to assess the human health and environmental risks resulting from contaminants in soil and groundwater. Course topics include evaluation of data sets, exposure calculation, chemical fate and transport, and development of conceptual site models.

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**GEO ENG 5235 Environmental Geological Engineering** (LEC 3.0)

Introduction to engineering geologic mapping for site selection for solid waste disposal facilities; landfill site selection, design, permitting, construction, operation, and closeout/reclamation. Prerequisites: Geo Eng 3175, accompanied or preceded by Civ Eng 3715.

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**GEO ENG 5237 Geological Aspects Of Hazardous Waste Management** (LEC 3.0)

Nature and classification of hazardous wastes; federal and state regulation for treatment and disposal; geological characterization of facility sites; design of impoundments, storage and containment facilities; ground water monitoring and protection; site permitting and licensing planning. Prerequisite: Geo Eng 3175.

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**GEO ENG 5239 Groundwater Remediation** (LEC 3.0)

A survey of conventional and innovative techniques for remediation of contaminated groundwater. Topics include groundwater cleanup standards, physico-chemical properties of groundwater and contaminants, fate and transport of contaminants in the subsurface, hydrogeologic site characterization, and selection process of a remedial technology. Various computer programs developed to assist in preliminary selection and design of remediation technologies will be used. Prerequisite: Geo Eng 5331.

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**GEO ENG 5247 Introduction to International Engineering and Design** (LEC 2.0)

A multi-disciplinary design course focused on sustainable design and technology transfer to developing countries. Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by Geo Eng 5211.

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**GEO ENG 5276 Advanced Environmental Aspects Of Mining** (LEC 3.0)

Applied and fundamental research issues pertaining to: permitting -- the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, nonmetal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Course project. (Co-listed with Min Eng 5742).

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**GEO ENG 5315 Advanced Statistical Methods in Geology and Engineering** (LEC 3.0)

Application of statistical methods to study of geologic materials and practices, with emphasis on reliable interpretation of laboratory and field data for water, hydrocarbon, and mineral exploration, research, and engineering as well as other aspects of geological engineering. Prerequisites: Geo Eng 4115 or Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117.

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**GEO ENG 5320 Groundwater Modeling** (LEC 3.0)

This course is an introduction to advanced modeling techniques for understanding flow and transport in porous media under different hydrologic conditions. Emphasis is placed on both theoretical and practical modeling considerations. Computer demonstrations are incorporated. Practical applications are emphasized. Prerequisite: Civ Eng 3330 or Geo Eng 5331.

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**GEO ENG 5331 Subsurface Hydrology** (LAB 1.0 and LEC 2.0)

Introduction to the theory and engineering concepts of the movement of subsurface fluids. Hydraulic characteristics of earth materials, aquifer characterization, and flow prediction. Engineering problems related to subsurface fluids. Prerequisites: Geo Eng 1150 or equivalent, Math 1215.

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**GEO ENG 5332 Fundamentals of Groundwater Hydrology** (LEC 3.0)

Focus on fundamental analysis and survey of groundwater hydrology with emphasis on practical geo-environmental and subsurface hydrology issues of interest to working professionals. Topics will include general hydrology, surface and subsurface interconnection, basic groundwater flow and well test analysis, and a brief intro to contaminant transport.

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**GEO ENG 5381 Intermediate Subsurface Hydrology And Contaminant Transport Mechs** (LAB 1.0 and LEC 2.0)

A study of the physical/chemical properties of rocks and sediments in the subsurface environment. Emphasis is put on waterrock properties such as permeability, capillarity, and mechanical dispersion. Both microscopic and macroscopic approaches are used. Prerequisites: Geo Eng 5331, Geo Eng 5332, or Geol 4411.

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**GEO ENG 5415 Soil Mechanics for Geoprosessionals** (LEC 3.0)

The basic principles of soil mechanics necessary for professionals to practice in the field of geoconstruction. Topics related to the practical aspects of engineering include: soil classification, index properties, water flow through soils, compaction, compressibility, and shear strength. These basic principles will be applied to real world problems.

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**GEO ENG 5441 Engineering Geology And Geotechnics** (LEC 3.0)

Study of procedures and techniques used to evaluate geologic factors for site selection and the design of engineered structures. Prerequisite: Geo Eng 3175.

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**GEO ENG 5443 Subsurface Exploration** (LAB 1.0 and LEC 2.0)

Lectures and field and laboratory exercises in the use of geologic and geophysical techniques for evaluation of subsurface geology and resources. Prerequisite: Geo Eng 1150.

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**GEO ENG 5471 Rock Engineering** (LEC 3.0)

Data requirements for design; engineering properties of rock; characterization of fractures and rock masses; stereonet analysis of discontinuities; graphic analysis of failure; ground stress distribution; tunnel construction methods; ground support principles; selection of tunneling equipment; and specifications for underground construction. Prerequisite: Geo Eng 3175.

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**GEO ENG 5556 Renewable Energy Systems** (LEC 3.0)

Introduction to the theory and performance prediction of typical renewable energy systems such as, but not limited to, those based on energy from the sun, wind and water, and geothermal. The use of environmental data, including stochastic modeling, for renewable energy system (including wind turbine, photovoltaic, and geothermal) design is addressed. Prerequisites: Math 3304, Physics 2135, and preceded or accompanied by Geo Eng 4115 or any Probability and Statistics class. Junior or senior standing is required.

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**GEO ENG 5575 Aggregates And Quarrying** (LEC 3.0)

Properties and uses of aggregates. Finding aggregate deposits and methods of extraction. Aggregate processing. Aggregate testing. Economics and politics of aggregates. Special topics in aggregates and quarrying. Prerequisites: Geo Eng 1150, Geo Eng 3175.

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**GEO ENG 5642 Military Geology** (LEC 3.0)

This course will familiarize geologists, geophysicists, civil and geological engineers with the fundamental principles of physical geology, geohydrology and geomorphology as applied to military problems, such as development of fortifications, core infrastructure, water resources and combat engineering requirements. Prerequisite: Geo Eng 3175 or graduate standing.

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**GEO ENG 5736 Geophysical Field Methods** (LEC 2.0 and LAB 1.0)

Imaging of selected subsurface features and engineering structures using various geophysical tools. Special emphasis is placed on ground penetrating radar and surface wave techniques. One field trip at student expense required. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5736).

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**GEO ENG 5761 Transportation Applications of Geophysics** (LEC 2.0 and LAB 1.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5761 and Civ Eng 5750).

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**GEO ENG 5782 Environmental and Engineering Geophysics** (LEC 2.0 and LAB 1.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 2222. (Co-listed with Geophys 5782).

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**GEO ENG 5810 Fundamentals of Space Resources** (LEC 3.0)

Introduction to the science of the mineral resources of space, and to the engineering of extracting them for human use.

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**GEO ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEO ENG 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEO ENG 6010 Seminar** (RSD 1.0)

Discussion of current topics. Prerequisite: Graduate student.

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**GEO ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEO ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEO ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**GEO ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

**GEO ENG 6146 Advanced Remote Sensing And Image Processing** (LEC 2.0 and LAB 1.0)

Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Geo Eng 5146. (Co-listed with Geology 6341).

**GEO ENG 6235 Advanced Concepts Of Environmental Geological Engineering** (LEC 3.0)

Application of the principles of geology to the solution of engineering problems in environmental protection and remediation. Topics will include the study of geologic processes and the evaluation of geologic materials as they affect the potential for groundwater contamination, susceptibility of soils to erosion, characterization of the geologic environment for site suitability and the analysis of the criteria necessary for the selection of technologies for minimizing environmental impact. Prerequisite: Graduate level course in environmental geologic studies.

**GEO ENG 6237 Advanced Geological & Geotechnical Design For Hazardous Waste Mgt** (LEC 3.0)

Geological and geotechnical design factors for hazardous waste management facilities and remedial actions (cleanup) of uncontrolled hazardous waste sites. Prerequisite: Geo Eng 5237 or consent of instructor.

**GEO ENG 6331 Advanced Subsurface Hydrology** (LEC 3.0)

Advanced treatment of selected topics in subsurface hydrology, including groundwater contamination, contaminant transport, land disposal of wastes, aquifer test analysis, injection well technology, etc. Applied hydrogeologic site analysis and flow and transport modeling through solution of selected case examples. Prerequisite: Geo Eng 5331 or equivalent.

**GEO ENG 6332 Numerical Methods In Subsurface Flow** (LEC 3.0)

Development of governing balance equations, constitutive laws and mathematical models of groundwater flow and contaminant transport in porous media. Solution of mathematical models by finite difference and finite element methods for various boundary and initial conditions. Prerequisites: Geo Eng 5331, Comp Sci 1970.

**GEO ENG 6400 Practice Oriented Project** (IND 3.0)

This class will consist of a single term project. Students will, in consultation with the instructor, pick a topic relevant to their studies, and produce a comprehensive, in depth, professionally written report, including a literature review on the state of the practice on that topic. Prerequisites: Limited to students enrolled in the Masters of Engineering (M.E.) in Geotechnics Program.

**GEO ENG 6407 Inca Civilization Geotechnical Engineering Practices** (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Civ Eng 6760).

**GEO ENG 6441 Geotechnical Construction Practice** (LEC 3.0)

Advanced level lecture topics on procedures used for site characterization, standards for earthquake grading and construction, including embankments, building pads, retention structures, roads, levees, and earthen dams. Specific emphasis on preparation of documents involved in such work and engineer's responsibilities. Prerequisite: Geo Eng 5441.

**GEO ENG 6477 Discontinuous Rock** (LEC 3.0)

Nature and properties of discontinuous rock masses, genesis and properties of joints, role of joints in rock shear strength, slope of stability of jointed rock, fracture flow hydrogeology. Modeling of the mechanical behavior of fractured rock. Prerequisite: Min Eng 4823 or Geo Eng 5471.

**GEO ENG 6625 Applications in Geological Engineering** (LEC 3.0)

Content is focused on practical aspects of geological engineering. Geotechnical, environmental and geohydrologic case studies are presented to illustrate concepts and relate theory to applications.

**GEO ENG 6736 Advanced Geophysical Methods** (LEC 1.0 and LAB 2.0)

Geophysical field data will be acquired at selected study sites with the objective of imaging the shallow subsurface and/or built structures. Registrants will process and interpret the acquired non-invasive imaging data using ground truth as a constraint. Prerequisite: Graduate Standing.

**GEO ENG 6782 Surface Waves (MASW) and Ground Penetrating Radar (GPR)** (LAB 1.0 and LEC 2.0)

Geological engineering applications of surface wave and ground penetrating radar methods are emphasized. Field data will be acquired, processed and interpreted. Prerequisites: Geo Eng 1150 or Civ Eng 3715 or equivalent, and graduate standing.

**GEO ENG 6784 Advanced Engineering And Environmental Geophysics** (LEC 3.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential induced polarization, seismic, electromagnetic and GPR methods as applied to the solution of engineering and environmental problems. Prerequisite: Admittance into USAES-S&T Co-operative Degree Program. (Co-listed with Geophys 5251).

## Information Science and Technology

Information science and technology (IS&T) offers an M.S. degree program. Information technology has transformed every aspect of our economy and society. Rapid spread of technology has generated the need for highly trained professionals to implement and maintain information systems. The M.S. in information science and technology is designed to educate students in the design, development, and successful application of information systems in organizations.

Also offered are a number of graduate certificates:

- Business analytics and data science
- Business intelligence
- Business project management
- Cybersecurity and information assurance management
- Digital media and web design
- Digital supply chain management
- Electronic and social commerce
- Enterprise resource planning
- Entrepreneurship and technological innovation
- Finance
- Financial technology
- Human-computer interaction and user experience
- Information systems project management
- Management and leadership
- Mobile business and technology

These graduate certificates are intended for students who wish to specialize and for working professionals who want to stay ahead of rapidly changing technology. Each graduate certificate program consists of a four-course sequence from existing graduate-level courses. Certificate credits earned by students admitted to the M.S. program will count toward their master's degree. Students admitted just to the certificate program will have non-matriculated status. However, if they complete the four-course sequence with a grade of "B" or better in each of the courses taken, they will be admitted to the M.S. program if they so choose. In addition, successful completion of the graduate certificate offered in the business program, with grades of "B" or better in each of the courses will also enable admission to the IS&T M.S. program. Admitted students must still meet the admissions requirements relative to undergraduate coursework prerequisites.

The faculty is active in studying the design and application of the web and has external support for research. Research experiences are integrated into the classroom experience. Specially equipped research laboratories are available to support studies in human-computer interaction and experiments with computer networks, as are general purpose computing laboratories that are available to all students. A large number of computing languages and special-purpose software tools are available on various platforms. While instruction and research are on the leading edge of information systems, the department endeavors to keep class sizes small to facilitate student and faculty interactions.

## Financial Assistance

Financial assistance is available to graduate students in the form of assistantships and fellowships. Research opportunities for advanced students exist. For application forms, contact the department.

## Additional Information

Contact us at 573-341-7216, bit@mst.edu or visit <http://bit.mst.edu>.

## Admission Requirements

In addition to the requirements set by the office of admissions and the office of graduate studies, specific requirements for admission to the M.S. in information science and technology (thesis or non-thesis) are as follows:

- Successful completion of an undergraduate degree from a recognized college or university with a GPA (grade point average or international equivalent) of 3.0/4.0 or better.
- Submission of scores from the Graduate Record Exam (GRE) or the Graduate Management Admissions Test (GMAT).
- TOEFL or IELTS scores must be submitted if English is not the candidate's natural language.
- Undergraduate coursework in Calculus; Statistics; Object-oriented Programming with Data Structures; Information Systems; Relational Database Management Systems; and Computer Architecture must be shown.

\*\*\*Please note that meeting the above requirements does not guarantee admission into the M.S. in information science and technology, but, rather, is used by the admissions committee in the decision-making process\*\*\*

## Degree Requirements

**M.S. with thesis:** The M.S. degree with thesis requires the completion of 24 hours of graduate course work (5000-level or above), 6 hours of research, and the successful completion and defense of a research thesis.

**M.S. without thesis:** The M.S. degree without thesis requires the completion of 30 hours of graduate course work (5000-level and above). Courses below the 5000-level will not count toward the M.S. degree, even if they are taken to fulfill prerequisites.

The following core courses are required of all M.S. students in information science and technology. These courses are designated to ensure that all IS&T masters students study the four information systems perspectives of networks and web design, human perception, application implementation, and organizational systems.

IS&T 5251	Technological Innovation Management and Leadership
IS&T 5885	Human-Computer Interaction
IS&T 6261	Advanced Information Systems Project Management
IS&T 6336	Foundations of Internet Computing

The department of business and information technology offers a variety of graduate certificates. Each certificate program consists of four courses and is open to persons holding a bachelor's, master's or Ph.D. degree in areas such as business, social sciences, technology, engineering, or related disciplines who have the required pre-requisites for the courses in the program. A student must maintain an average cumulative grade point of 3.0 or better on a 4.0 scale in the certificate courses in order to receive the graduate certificate.

Students may apply to be admitted only to a graduate certificate program. If admitted, the student will have non-degree graduate status but will earn graduate credit for the courses completed. If a student completes the four graduate certificate courses with a grade of B or better in each of the courses taken, the student may be admitted to the master of business administration or to the master of science in information science and technology if the student so chooses. A student must, however, follow the normal application process and meet the undergraduate coursework prerequisites. The graduate certificate credits will count toward the student's MBA or M.S. degree.

Details about some of the graduate certificates are listed below; others are listed in the business administration section of the catalog.

## AI, Machine Learning and Automation in Business

Artificial Intelligence is a disruptive technology in the business realm with transformational impact. From detecting malware and preventing money laundering to automating insurance claims and optimizing inventory and improving product recommendations and more, AI will continue to necessitate changes in core business processes and models. Within the past few years, machine learning, while not fully tapped in the business sphere, has become more effective and widely utilized. Tomorrow's leaders and managers will need to integrate machine learning where appropriate, incorporating its capabilities with those of humans. The design and implementation of new combinations of technologies with human skills to meet customers' needs will require critical thinking skills, creativity, and project planning.

A student admitted to this graduate certificate must complete four courses:

Required Courses:

BUS 5730 Machine Learning and Artificial Intelligence for Business

IS&T 5535 Machine Learning Algorithms and Applications

Elective Courses (choose two):

BUS 6723 Artificial Intelligence, Robotics, and Information Systems

IS&T 5520 Data Science and Machine Learning with Python

IS&T 6443 Information Retrieval and Analysis

IS&T 6445 Database Marketing

IST 6450: Information Visualization

ERP 5410: Use of Business Intelligence

## Business Analytics and Data Science

Data analytics facilitates realization of objectives by identifying trends, creating predictive models for forecasting, and optimizing business processes for enhanced performance. Three main categories of analytics are:

- Descriptive - the use of data to find out what happened in the past.
- Predictive - the use of data to find out what could happen in the future.
- Prescriptive - the use of data to prescribe the best course of action for the future.

Big data is an emerging phenomenon. Computing systems today are generating 15 petabytes of new information every day—eight times more than the combined information in all the libraries in the U.S.; about 80% of the data generated every day is textual and unstructured data.

This graduate certificate is one of three graduate certificates offered by cooperating departments at Missouri S&T to fulfill the needs in the area described as "big data." The other two graduate certificates are:

- Big Data and Security
- Big Data Management and Analytics

A student admitted to this graduate certificate must complete four courses:

IS&T 5420	Business Analytics and Data Science
IS&T 6450	Information Visualization
One course from the following:	
IS&T 5001	Special Topics (Data Methodologies Using Python)
ERP 5410	Use of Business Intelligence
COMP SCI 5204	Regression Analysis
COMP SCI 5402	Introduction to Data Mining
COMP SCI 6304	Cloud Computing and Big Data Management
COMP ENG 6330	Clustering Algorithms
STAT 5814	Applied Time Series Analysis
One course from the following:	
IS&T 6443	Information Retrieval and Analysis
IS&T 6444	Essentials of Data Warehouses
IS&T 6445	Database Marketing
IS&T 6448	Building the Data Warehouse
IS&T 6887	Research Methods in Business and IS&T
ERP 5210	Performance Dashboard, Scorecard and Data Visualization
ERP 6610	Advanced Customer Relationship Management in ERP Environment
ERP 6220	Data Modeling & Visualization Prototyping for Enterprise Decision Dashboards
BUS 6425	Supply Chain and Project Management

## Business Intelligence

Interest in business intelligence has been a recent strong theme among employers. Medium and large-sized businesses are especially interested.

In order to make appropriate decisions, upper-level administration of an organization needs to draw data together from different systems in order to get a unified picture of the status and performance of an organization and present it in helpful ways. Examples include the development of organizational scorecards, dashboards, and other tools that provide a picture of how an organization is performing. People capable of creating and maintaining such information are needed.

This graduate certificate focuses on the technologies that allow an organization to make effective business decisions based on operational data pulled together from many different sources inside and organization. The target audience consists of any individual who would manage any type of IT professionals, database administrators, business analysts, and any person who would need to understand the technologies and their capabilities.

A student admitted to this graduate certificate must complete four courses:

ERP 5410	Use of Business Intelligence
IS&T 6444/ ERP 6444	Essentials of Data Warehouses
Two courses from the following list:	
ERP 5110	Enterprise Resource Planning Systems Design and Implementation
ERP 5210	Performance Dashboard, Scorecard and Data Visualization
ERP 6610	Advanced Customer Relationship Management in ERP Environment
ERP 6220	Data Modeling & Visualization Prototyping for Enterprise Decision Dashboards
IS&T 6443	Information Retrieval and Analysis
IS&T 6445	Database Marketing

## Cybersecurity and Information Assurance Management

Cybersecurity is one of the fastest growing employment segments in IT. As technology grows and progresses, with our devices and lives becoming more and more interconnected, the challenges of cybersecurity and information assurance will continue to grow. This presents a career to those with the necessary skills that will be exciting, rewarding, fast-paced, and highly sought after.

A student admitted to this graduate certificate must complete four courses:

BUS 5910	Privacy and Information Security Law
IS&T 6780	Adv Human and Organizational Factors in Cybersecurity

Two courses from the following list:

ERP 5240	Enterprise Application Development and Software Security
IS&T 6335	Mobile Technology for Business
IS&T 6336	Foundations of Internet Computing
IS&T 6641	Advanced Digital Commerce and the Internet of Things

## Digital Media and Web Design

Digital media is growing as consumers change the way they access information. In pursuing this certificate, students will acquire the skills and knowledge to create, design and analyze digital media. The focus will be on the media itself, the social/digital network that connects these media, the interfaces that connect these media with users, and the application of these skills in business and other creative contexts.

Thus this certificate program will address the pressing demand and opportunities for graduates with advanced knowledge and skills in areas such as networked communication and marketing, web-based media creation and design, and methods for designing and building effective human-media interfaces.

A student admitted to this graduate certificate must complete four courses:

IS&T 6654	Advanced Web and Digital Media Development
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Two courses from the following list:

IS&T 5885	Human-Computer Interaction
IS&T 6680	Advanced Web and New Media Studies
MKT 5310	Digital Marketing and Promotions

One course from the following:

IS&T 5652	Advanced Web Development
IS&T 5886	Prototyping Human-Computer Interactions

## Digital Supply Chain Management

Success in today's marketplace requires that organizations deliver products and services that provide easily identified value for their customers. This certificate draws on strengths within two departments to integrate source (strategic procurement and supply management), production (manufacturing and service operations), and delivery processes (demand fulfillment), with a focus on the use of information technologies as the critical enabler of supply chain efficiencies and responsiveness.

The certificate is designed to give students the tools and ideas that help shape and define the various components of value creation. Students can gain knowledge and skills in the full spectrum of supply chain activities: supplier relationships, purchasing management, operations and inventory

management, logistics and transportation, quality management, and information technology.

A student admitted to this graduate certificate must complete four courses:

ERP 5110	Enterprise Resource Planning Systems Design and Implementation
ERP 5310	Supply Chain Management Systems in an ERP Environment

One course from the following list:

MECH ENG 5708	Rapid Product Design And Optimization
BUS 6425	Supply Chain and Project Management

One course from the following list:

ERP 5410	Use of Business Intelligence
ERP 6120	Enterprise Resource Planning: Systems Config and Integration
ERP 6610	Advanced Customer Relationship Management in ERP Environment
MECH ENG 5656	Design For Manufacture
MECH ENG 5757	Integrated Product And Process Design
MECH ENG 5760/ AERO ENG 5760	Probabilistic Engineering Design
MECH ENG 5763	Computer Aided Design: Theory and Practice

## Electronic and Social Commerce

Social commerce is just one sub-set of e-commerce, however it is growing rapidly. The department of business and information technology (BIT) has leveraged its' strengths in both business and technology for this program, which is designed to create successful students by developing skills in technological business practices that will provide opportunities for succeeding in today's fast paced world. To that end, the program focuses on the following competencies:

- Management concepts applied to IT
- Management concepts applied to support of electronic commerce
- Use of business processes in IT integration
- Competitive advantage through IT
- Electronic commerce through collaborative shopping

A student admitted to this graduate certificate must complete four courses:

IS&T 6641	Advanced Digital Commerce and the Internet of Things
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One course of the following:

IS&T 5251	Technological Innovation Management and Leadership
BUS 6723	Artificial Intelligence, Robotics, and Information Systems Management

Two courses from the following list:

IS&T 5168/ PHILOS 4368	Law and Ethics in E-Commerce
IS&T 5652	Advanced Web Development
IS&T 5885	Human-Computer Interaction
IS&T 5886	Prototyping Human-Computer Interactions
IS&T 6335	Mobile Technology for Business
IS&T 6445	Database Marketing
IS&T 6680	Advanced Web and New Media Studies
MKT 5310	Digital Marketing and Promotions
MKT 6580	Advanced Marketing Strategy

## Enterprise Resource Planning (ERP)

Corporations worldwide have focused on improving business processes for the past two decades. In fact, while most Fortune 500 companies have already adopted enterprise resource planning (ERP) systems, now

many midsize companies are also planning ERP implementations. With a commitment to keep pace with these changes in business processes and technology, the University of Missouri system joined SAP's™ University Alliance and Microsoft's™ University Alliance programs in order to continue and expand classroom capabilities for integrating ERP software into the curriculum.

ERP systems can be used to reinforce many of the concepts covered in the business discipline. ERP systems incorporate state-of-the-art technology, providing a comprehensive teaching tool for business and for information systems. Universities that have successfully incorporated an ERP system into their curricula find unprecedented student demand for those subjects.

ERP can be viewed as a combination of business management practice and technology, where information technology integrates with a company's core business processes to enable the achievement of specific business objectives. This certificate prepares students for positions as both technical and business consultants in the ERP field.

A student admitted to this graduate certificate must complete four courses:

ERP 5110	Enterprise Resource Planning Systems Design and Implementation
ERP 6120	Enterprise Resource Planning: Systems Config and Integration
Two additional ERP courses at the 5000 level or above, such as:	
ERP 5240	Enterprise Application Development and Software Security
ERP 5210	Performance Dashboard, Scorecard and Data Visualization
ERP 5310	Supply Chain Management Systems in an ERP Environment
ERP 5410	Use of Business Intelligence
ERP 5510	ERP System Administration
ERP 6220	Data Modeling & Visualization Prototyping for Enterprise Decision Dashboards
ERP 6444/ IS&T 6444	Essentials of Data Warehouses
ERP 6610	Advanced Customer Relationship Management in ERP Environment

## Human-Computer Interaction and User Experience

There is a growing demand within industry for workers with expertise in human-computer interaction (HCI), who generally hold titles such as interface designer; usability researcher analyst; usability engineer; user experience specialist; or information architect. HCI specialists bridge the gap in organizations between groups who build the technologies and groups who use the technologies. The qualifications for these positions generally fall into the following categories:

- Knowledge of human-computer interaction principles
- Skills in collecting user requirements
- Skills in developing prototypes, both low fidelity (e.g., paper) and high fidelity (e.g., html mock-up)
- Skills in evaluation of the impact of technologies on humans

A student admitted to this graduate certificate must complete four courses:

IS&T 5885	Human-Computer Interaction
IS&T 5886	Prototyping Human-Computer Interactions
IS&T 5887	Human-Computer Interaction Evaluation

One course from the following:

IS&T 6680	Advanced Web and New Media Studies
IS&T 6887	Research Methods in Business and IS&T

## Information System Project Management

Managing the development of large software systems is significantly different from managing construction or research projects. However, some of the tools developed for traditional project management continue to have value and can be adapted to development of software.

This certificate aims to equip students with a set of tools that will allow them to achieve Project Management Institute (PMI) standards in the project management area to successfully manage resources, and to analyze, evaluate and improve complex projects.

A student admitted to this graduate certificate must complete four courses:

IS&T 6261	Advanced Information Systems Project Management
ENG MGT 5320	Project Management
ENG MGT 6322	Case Studies in Project Management
ENG MGT 6323	Global Project Management

## Mobile Business and Technology

Interest in the use of mobile technology among organizations has seen a strong, upward trend over the past few years. The proliferation of smart phone and tablet devices has presented organizations with new challenges creating and developing a coherent strategy associated with this new innovation. In order to create this strategy, organizations will need an understanding of the mobile industry in general and specific technologies supporting the trend. People capable of creating and maintaining mobile technology strategies are needed.

This certificate is designed to cover the mobile industry as well as the technologies, devices, operating systems, user interface design, and tools of mobile applications. The focus will be on the mobile industry and technologies that allow an organization to make decisions in this dynamic domain.

A student admitted to this graduate certificate must complete four courses:

IS&T 6335	Mobile Technology for Business
ERP 5240	Enterprise Application Development and Software Security
Two courses from the following list:	
ERP 5210	Performance Dashboard, Scorecard and Data Visualization
ERP 5310	Supply Chain Management Systems in an ERP Environment
ERP 6610	Advanced Customer Relationship Management in ERP Environment
IS&T 5652	Advanced Web Development
IS&T 5886	Prototyping Human-Computer Interactions

**Carla Pauline Bates**, Assistant Teaching Professor  
PHD University of Missouri-Columbia  
Learning styles, learning technologies.

**Randy Lawrence Canis**, Adjunct Professor  
JD University of Missouri-Columbia  
Privacy and information security law, patent law, intellectual property for computer scientist, legal environment for engineers.

**Langtao Chen**, Assistant Professor  
PHD Georgia State University  
Data analytics, human-computer interaction, social media, health informatics, machine learning, gameful design.

**Yu Hsien Chiu**, Associate Teaching Professor  
MASTER University of Wisconsin-Milwaukee  
Enterprise resource planning, management information systems, business intelligence.

**Cecil Chua**, Associate Professor  
PHD Georgia State University

**Craig C Claybaugh**, Associate Professor  
PHD University of Wisconsin-Milwaukee  
Enterprise resource planning, information technology vendor-client relationships, online trust, social networking.

**Cassandra Carlene Elrod**, Associate Professor  
PHD University of Missouri-Rolla  
Marketing in higher education, operations management, supply chain management, continuous improvement, project management, quality, and lean enterprise.

**Li-Li Eng**, Associate Professor  
PHD University of Michigan Ann Arbor  
Financial and managerial accounting, international accounting.

**Hanqing Fang**, Assistant Professor  
PHD Mississippi State University  
Strategic management, family business, entrepreneurship.

**Barry B Flachsbar**, Professor Emeritus  
PHD Stanford University  
Large databases, manufacturing information systems, information systems project management, team building and leadership, machine learning, and artificial intelligence.

**Nobuyuki Fukawa**, Associate Professor  
PHD Louisiana State University  
Consumer behavior, marketing research, marketing strategy.

**Richard H Hall**, Emeritus  
PHD Texas Christian University  
Human-computer interaction with a focus on learning technologies.

**Michael Gene Hilgers**, Professor  
PHD Brown University  
Modeling and simulation, learning technologies, and human-computer interaction.

**Bih-Ru Lea**, Associate Professor  
PHD Clemson University  
Enterprise resource planning, performance dashboards, accounting information systems, data visualization, business process integration, and supply chain management.

**Yu Liu**, Assistant Professor  
PHD University of Oregon  
Empirical corporate finance, investment, OTC market, public finance, and political economics.

**Chris J Merz**, Adjunct Instructor  
PHD University of California-Irvine  
Utilization of statistics and databases in marketing activities

**Fiona Fui-Hoon Nah**, Professor  
PHD University of British Columbia  
Management information systems, E-commerce, mobile commerce, human-computer interaction.

**Nicholas Oswald**, Adjunct Instructor  
MASTER Missouri University of Science & Technology  
Human-computer interaction, implementing information systems, management information system, system analysis and design.

**Keng Leng Siau**, Professor  
PHD University of British Columbia  
Artificial intelligence/machine learning, business intelligence/analytics, design science, mobile, and ubiquitous business.

**Sarah Margaret Stanley**, Associate Professor  
PHD Saint Louis University  
Brand relationships, advertising effectiveness, social marketing and its effects on consumer brand choice.

**Wen-Bin Yu**, Associate Professor  
PHD University of Louisville  
Business intelligence, text mining, data mining, demand forecasting, simulation, and agent bases systems.

**Hongxian Zhang**, Assistant Professor  
PHD University of Texas at San Antonio  
Corporate finance, investments, public pension funds.

**IS&T 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**IS&T 5001 Special Topics** (LEC 0.0-6.0)  
This is designed to give the department an opportunity to test a new course. Variable title.

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**IS&T 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**IS&T 5099 Research** (IND 0.0-15)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**IS&T 5131 Foundations of Computer Architecture** (LEC 3.0)  
Design-oriented foundations of computer components and operation. Standard codes; number systems; base conversions; computer arithmetic; boolean algebra; operating system components including memory management, device management; plus related computer architecture topics. Research paper required. Prerequisites: Graduate Standing, strong programming knowledge.

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**IS&T 5168 Law and Ethics in E-Commerce** (LEC 3.0)

Provides the ethical framework to analyze the ethical, legal, and social issues that arise for citizens and computer professionals regarding the computerization of society. Topics include: free speech, privacy, intellectual property, product liability, and professional responsibility. (Co-listed with Philos 4368).

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**IS&T 5251 Technological Innovation Management and Leadership** (LEC 3.0)

The course focuses on the knowledge and skills necessary for the development and implementation of effective strategies for the management of technology-based organizations. This involves: developing a general management perspective on technology and innovation, examining the problems of new product development, identifying distinctive technological competencies, licensing and marketing technologies, assessing the organizational and industrial context of technology. Prerequisite: Senior or Graduate Standing.

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**IS&T 5420 Business Analytics and Data Science** (LEC 3.0)

Analysis of large business data sets via statistical summaries, cross-tabulation, correlation, and variance matrices. Techniques in model selection, prediction, and validation utilizing general linear and logistic regression, Bayesian methods, clustering, and visualization. Extensive programming in R is expected. Prerequisites: Calculus, Statistics, and Programming knowledge.

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**IS&T 5423 Foundations of Data Management** (LEC 3.0)

Foundational concepts of database management systems. Issues in database architecture, design, administration, and implementation. Extensive use of SQL with Oracle to create and manage databases. Significant project dealing with triggers or stored procedures. Prerequisites: Strong programming knowledge required.

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**IS&T 5520 Data Science and Machine Learning with Python** (LEC 3.0)

Examines data science methodologies for scraping, manipulating, transforming, cleaning, visualizing, summarizing, and modeling large-scale data as well as supervised and unsupervised machine learning algorithms applied in various business analytics and data science scenarios. Python libraries such as Pandas, NumPy, Matplotlib, and Scikit-learn are utilized. Prerequisites: One of Stat 3111, Stat 3113, Stat 3115, or Stat 3117; one of IS&T 1552, IS&T 1562, Comp Sci 1575; for Graduate Students: knowledge of calculus, statistics, and programming.

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**IS&T 5535 Machine Learning Algorithms and Applications** (LEC 3.0)

Introduces techniques of modern machine learning methods with applications in marketing, finance, and other business disciplines. Topics include regression, classification, resampling methods, model selection, regularization, decision trees, support vector machines, principal component analysis, and clustering. R programming is required. Prerequisites: One of Stat 3111, Stat 3113, Stat 3115, Stat 3117; one of IS&T 1552, IS&T 1562, Comp Sci 1575; or Graduate Standing with knowledge of calculus, statistics, and programming.

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**IS&T 5652 Advanced Web Development** (LEC 3.0)

Advanced web development techniques to provide dynamic interaction; methods for extracting and delivering dynamic information to/from web servers - a hands-on approach. Emphasis on interaction with servers; mobile software development; processing of graphics and web video. Project work is required. Prerequisites: IS&T 4654; one of IS&T 1551, IS&T 1561.

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**IS&T 5885 Human-Computer Interaction** (LEC 3.0)

Introduction to the field of Human-Computer Interaction (HCI). Students examine issues and challenges related to the interaction between people and technology. The class explores the social and cognitive characteristics of people who use information systems. Students learn techniques for understanding user needs, interface prototyping & interface evaluation.

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**IS&T 5886 Prototyping Human-Computer Interactions** (LEC 3.0)

This course explores novel HCI and UX technologies as well as methods and tools for creating system prototypes, including best practices and guidelines for optimal user experiences. Example concepts include mobile applications, behavioral monitoring, gamification, natural user interfaces, haptics, and computers as social actors. Prerequisite: Preceded or accompanied by IS&T 5885.

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**IS&T 5887 Human-Computer Interaction Evaluation** (LEC 3.0)

This course covers research and analysis methods and tools for evaluation of the impact of information technology systems on humans and organizations. The focus will be on practical evaluation with the goal of providing recommendations for improving system functionality and usability. Prerequisite: Preceded or accompanied by IS&T 5885.

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**IS&T 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**IS&T 6001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

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**IS&T 6050 Continuous Registration** (LEC 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**IS&T 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**IS&T 6261 Advanced Information Systems Project Management** (LEC 3.0)

Project management principles, first from a general perspective, and then focused specifically on information system application development are explored. Topics include requirements analysis, project scheduling, risk management, quality assurance, testing, and team coordination. Report writing and research literature searches are required. Prerequisites: Strong programming knowledge required.

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**IS&T 6335 Mobile Technology for Business** (LEC 3.0)

Overview of mobile technology use in business environments. Topics include: mobile industry; mobile network and wireless standards; mobile devices; mobile web design and app development; social and user experience issues; mobile marketing and commerce. Project required.

**IS&T 6336 Foundations of Internet Computing** (LEC 3.0)

The foundations of Internet Computing include computer networks and Web sites. Networks are covered thoroughly and research directions for networking and information security are discussed. Web site design and research findings about site usability considerations are examined. Prerequisite: IS&T MS entrance requirements, including solid programming knowledge.

**IS&T 6443 Information Retrieval and Analysis** (LEC 3.0)

Covers the applications and theoretical foundations of organizing and analyzing information of textual resources. Topics include information storage and retrieval systems, web search engines, text mining, collaborative filtering, recommender systems. Students will also learn the techniques with the use of interactive tools such as SAS. Prerequisite: ERP 5410 or statistics knowledge.

**IS&T 6444 Essentials of Data Warehouses** (LEC 3.0)

This course presents the topic of data warehouses and the value to the organization. It takes the student from the database platform to structuring a data warehouse environment. Focus is placed on simplicity and addressing the user community needs. Project required. Prerequisite: IS&T 5423 or equivalent relational database experience. (Co-listed with ERP 6444).

**IS&T 6445 Database Marketing** (LEC 3.0)

Intro to methods and concepts used in database marketing: 1) predictive modeling techniques (e.g., regression, decision trees, cluster analysis) and 2) standard processes for mapping business objectives to data mining goals to produce a deployable marketing model. Metrics like lifetime value of a customer and ROI will be covered. Several application areas covered. Prerequisite: Statistics understanding, programming understanding, familiarity with spreadsheets.

**IS&T 6448 Building the Data Warehouse** (LEC 3.0)

Data modeling and processes needed to populate a data warehouse; tradeoffs among several models and tools; technical issues that are faced, such as security, schemas, Web access, other reporting techniques. Prerequisite: IS&T 6444.

**IS&T 6450 Information Visualization** (LEC 3.0)

Topics/activities include: the visualization development framework, traditional presentations of data, human perception and aesthetics, colorspace theory, visualization algorithms and software, case studies of modern topology, research into visualization algorithms and implementations in R. Students will produce significant programs and visualizations. Prerequisites: Statistics, Calculus, and Programming Knowledge.

**IS&T 6641 Advanced Digital Commerce and the Internet of Things** (LEC 3.0)

Fundamental concepts of management and application to IT and support of commerce. Examines use of IT in business processes and everyday interactions such as IoT. Explores management issues of integrating IT into processes to run businesses better. Includes a major end-of-semester project. Prerequisites: Knowledge of management information systems.

**IS&T 6654 Advanced Web and Digital Media Development** (LEC 3.0)

This course covers advanced techniques and tools for the design and development of web-based media, including text, graphics, animation, audio, and video. This course is an advanced version of Web and Digital Media Development, with additional assignments.

**IS&T 6680 Advanced Web and New Media Studies** (LEC 3.0)

The course covers web culture, including topics such as social media; citizen journalism, crowd intelligence, privacy, and copyright. This course is an advanced version of Intro to Web Studies, with additional assignments.

**IS&T 6780 Adv Human and Organizational Factors in Cybersecurity** (LEC 3.0)

In-depth examination of human and organizational factors in cybersecurity and information assurance. Examines current challenges to protecting the integrity, availability, and confidentiality of information, as well as tools, methods, principles, and analytics for fraud prevention, insider threat detection, and forensic investigations. Project Required. Prerequisite: None, but recommended: IS&T 3333 or IS&T 6336 or Comp Sci 3600 or another introductory cybersecurity or information assurance course.

**IS&T 6887 Research Methods in Business and IS&T** (LEC 3.0)

This course covers quantitative and qualitative research methods for exploring the interaction between people and information technologies. The course covers techniques and tools for carrying out literature reviews, forming research goals, designing research, conducting data analyses; and preparing manuscripts and live presentations. (Co-listed BUS 6887).

## Manufacturing Engineering

Manufacturing uses advanced technologies to transform materials into new products or parts of products. Today's manufacturing industry includes (but is not limited to) aerospace, biotechnology, electronic equipment manufacturing, engineering in machining and equipment, food processing and supply, light metals, marine industries, etc.

Missouri S&T's manufacturing engineering education program offers the interdisciplinary master of science (M.S.) and master of engineering (M.E.) degrees on campus or through distance learning via the internet. Both degree programs are intended for a student with a B.S. degree in engineering to learn about modern manufacturing technologies involving computers and automation.

Also offered are graduate manufacturing engineering certificate programs, including manufacturing systems and CAD/CAM and rapid product realization for working professionals who want to stay ahead of rapidly changing technology.

The M.S. program is a research-oriented degree where the courses supplement the thesis research. The M.E. program is designed such that

the course selection is flexible and the student is allowed to take courses pertaining to his or her area of interest. A practice-orientated project is required by the M.E. program, which provides an opportunity for the student to participate in a practical project related to a manufacturing process. The M.E. program is structured so that individuals, such as working engineers, who wish to improve their knowledge and skills can complete their degree in one year.

The M.S. program requires 30 credit hours and a thesis:

- 12 credit hours from the manufacturing core areas
- 6 credit hours of 6000-level courses in manufacturing
- 6 to 9 credit hours for thesis research
- 3 to 6 credit hours of graduate courses in manufacturing as approved by the academic advisor

The M.E. program requires 30 credit hours and a practice-oriented project. The course requirements include 12 credit hours from the manufacturing core areas, 6 credit hours of 6000-level courses in manufacturing; 3 credit hours of approved mathematics/computer science or any suggested manufacturing courses, 3 credit hours for work related to the practice-oriented project, and 6 credit hours of graduate courses in manufacturing. The practice-orientated project is defined by the student and academic advisor. At the end of the project experience, the student should demonstrate not only the proficiency of operating certain manufacturing processes, but also the capability to improve the process. At the end of the M.E. program, a presentation and a report documenting the practice oriented projects are required. For both programs, at most 6 credit hours of 4XXX level classes can be completed in the degree.

For both programs, each student must take at least one course from each of the core areas in manufacturing engineering during his or her first two semesters of graduate work. The core requirements may be deemed satisfied if a student has already taken a core course as a technical elective in his or her undergraduate program, thus allowing more freedom in the selection of other courses. The related courses in manufacturing core areas are selected and offered from various departments.

The manufacturing core areas include:

- Materials and Manufacturing Processes
- Process, Assembly and Product Engineering
- Manufacturing Competitiveness
- Manufacturing System Design

The graduate committee for each student in the interdisciplinary Master of Science degree program will consist of three faculty of which at least two must be from the Manufacturing Education Committee (MEC). The major advisor should also be a member of the Manufacturing Education Committee. The master of engineering student does not need a committee, but the advisor should be from MEC. MEC is formed by over 40 faculty members from various departments, such as ceramic engineering, chemical engineering, computer science, electrical and computer engineering, engineering management, mechanical and aerospace engineering, metallurgical engineering, mining engineering, and business administration. For details regarding the application, curriculum, courses in manufacturing core areas, and MEC faculty, you may also wish to explore the program's web page at: <http://mae.mst.edu>. Some examples of research areas in which you can specialize include:

- Additive Manufacturing
- Manufacturing Process Modeling
- Design for Manufacturing/Assembly
- CAD/CAM/CIM
- Product/Process Development
- Manufacturing Management
- Manufacturing Processes
- Manufacturing Materials
- Lean Manufacturing
- Rapid Product Realization
- Assembly & Automation
- CNC machining
- Environmentally Friendly Manufacturing
- Product Quality Control

This is a truly interdisciplinary program, which will provide you with a variety of options in manufacturing. The existing laboratories which can be used in this proposed program include Innovative Additive Manufacturing Laboratory, Industrial Automation and Flexible Manufacturing, Laser-Aided Manufacturing Processes (LAMP) Lab. Rapid Prototyping Laboratory, Laser-Based Manufacturing Laboratory, Caterpillar Mechatronics Laboratory, The Precision Motion Control Laboratory, Manufacturing Automation and Control Laboratory (MAC Lab), Multiscale Manufacturing Laboratory, Metal and Ceramic Processing Laboratory, Materials Design and Manufacturing Laboratory, Femtosecond Laser Nanophotonics Laboratory, Thermal Radiation Laboratory, Structural Health Monitoring & Non-Destructive Evaluation Laboratory, and Foundry to Melt and Cast Ferrous and Non-ferrous Alloys.

The graduate certificate program consists of a four-course sequence from existing graduate-level courses. While the students admitted to the Certificate Program will have non-matriculated status, if they complete the four-course sequence with a grade of "B" or better in each of the courses taken, they will be admitted to the M.S. program if they so choose. The Certificate credits taken by students admitted to the M.S. program will count toward their master's degree.

## CAD/CAM & Rapid Product Realization Certificate

One each from the four core areas in the Manufacturing Engineering program as outlined below:

### Course I

MECH ENG 5763	Computer Aided Design: Theory and Practice
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### Course II

MECH ENG 6659	Advanced Topics in Design and Manufacturing
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### Course III

Select one of the following:

ENG MGT 5515/ MECH ENG 5757	Integrated Product And Process Design
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MECH ENG 5708	Rapid Product Design And Optimization
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### Course IV

Select one of the following:

AERO ENG 5760	Probabilistic Engineering Design
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MECH ENG 5656	Design For Manufacture
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## Manufacturing Systems Certificate

For the Manufacturing Systems Graduate Certificate Program the students will need to take four course sequences, one each from the

four course areas in the Manufacturing Engineering program as outlined below:

#### Course I-Materials and Manufacturing Processes

Select one of the following:

MECH ENG 5220	Advanced Mechanics of Materials
MECH ENG 5236	Fracture Mechanics
MECH ENG 5282	Introduction to Composite Materials & Structures
MECH ENG 6659	Advanced Topics in Design and Manufacturing

#### Course II-Process, Assembly and Product Engineering

Select one of the following:

ENG MGT 5515/ MECH ENG 5757	Integrated Product And Process Design
MECH ENG 5708	Rapid Product Design And Optimization
MECH ENG 5763	Computer Aided Design: Theory and Practice

#### Course III-Manufacturing Competitiveness

Select one of the following:

ENG MGT 5710	Six Sigma
ENG MGT 5613	Value Analysis
ENG MGT 5615	Production Planning And Scheduling
ENG MGT 5714	Statistical Process Control
ENG MGT 6611	Lean Systems
AERO ENG 5760	Probabilistic Engineering Design
ERP 5110	Enterprise Resource Planning Systems Design and Implementation

#### Course IV-Manufacturing Systems Design

Select one of the following:

ENG MGT 5314	
MECH ENG 5478	Mechatronics
MECH ENG 5655	Manufacturing Equipment Automation
MECH ENG 5656	Design For Manufacture

## Materials Science and Engineering

The materials science and engineering department offers a variety of educational and research opportunities for graduate study including degree programs in materials science and engineering, ceramic engineering, and metallurgical engineering. The department offers the following degrees: M.S. and Ph.D. in materials science and engineering, M.S. and Ph.D. in ceramic engineering, and M.S. and Ph.D. in metallurgical engineering. Further information regarding these degree programs may be found below and under the individual degree programs within this catalog.

The requirement for entry into one of these programs includes a baccalaureate degree in materials science or engineering, ceramic engineering or science, glass science or technology, or metallurgical science or engineering. A baccalaureate degree in physics, chemistry, chemical engineering, or related discipline may also be acceptable.

In the areas of glass, ceramic, and biomaterials, the department carries out research in electronic ceramics, high temperature materials, structural ceramics, composites, ceramic processing, laser glasses, and nuclear waste encapsulation glasses. Fundamental and applied interests include structure and its relation to the properties of ceramics and glasses; defect chemistry, thermochemistry and phase equilibria; electrical, dielectric, optical, thermal and mechanical properties of ceramics; ceramic-ceramic, ceramic-metal, and ceramic-polymer composites; compositional effects on the optical properties and chemical corrosion of glass; solid oxide fuel cells; high temperature superconducting ceramics; ferroelectric ceramics; glasses and ceramics for biomedical applications such as drug delivery and medical implants; and processing, forming, and microstructure control of structural and

functional ceramics. The department has extensive facilities for the synthesis, forming, and fabrication of ceramics and glasses, as well as for the detailed characterization of the properties of ceramics. A mechanical testing laboratory is available for characterizing mechanical properties under controlled temperature and atmospheric conditions.

In the areas of metallurgical science and engineering, the department carries out research in physical and mechanical metallurgy, extractive metallurgy, metals casting, joining and forming, and manufacturing metallurgy. Principal research interests include steel manufacturing and processing, additive manufacturing of advanced metallic materials, electro-metallurgical processes, computation methods for materials synthesis and processing, radiation effects on materials, environmental aspects of metal manufacturing, and treatment of metals industry wastes. Capabilities for research in these areas include: (1) a department foundry with facilities for green sand casting, centrifugal casting, lost foam casting, and permanent mold casting, and metal joining, (2) controlled hot rolling and quenching, (3) multiple advanced additive manufacturing systems, (4) physical testing of metals under controlled temperature and atmospheric conditions, and (5) pilot scale electrowinning, electrorefining and solvent extraction facilities.

In the area of biomaterials the department carries out research in the synthesis and characterization of novel biomaterials, the design and fabrication of scaffolds for tissue engineering of biological tissues, interactions of biomaterials with living systems, and tissue-engineered restoration of biological tissues.

The department also has a strong affiliation with the Materials Research Center (MRC) at Missouri S&T, which houses major instrumentation for materials characterization. Faculty members within the MSE department are either senior research investigators or research investigators in this nationally recognized center. Facilities available within the MRC to support graduate research include electron microscopy, thermal analysis, Auger Electron Spectroscopy, FIB (Focused Ion Beam) x-ray diffraction, together with grazing incidence for film analysis, among others. Extensive capabilities for materials coatings, preparation and analysis are also available.

## Degree Requirements

M.S. and Ph.D. degrees are offered in materials science and engineering. Students may apply for either degree and may be admitted directly to the Ph.D. program upon approval (i.e., there is no M.S. requirement). Depending upon their intended career path, students may be encouraged to pursue one of the MSE graduate degrees or other degree programs noted above.

The total number of hours required for the M.S. in materials science and engineering is 30. The M.S. with thesis is oriented toward the completion of a research project and the degree requirements are 18 hours of course work and 12 hours of research. It is recommended that the student complete the core courses offered by the department including MS&E 6110, MS&E 6120, and MS&E 6130 which are graduate level crystallography, thermodynamics and kinetics. At least 6 hours of course work must be 6000-level courses. It is recommended that six additional hours be completed outside of the department. The other courses are chosen with the approval of the advisor.

For the non-thesis M.S. degree in materials science and engineering, 30 hours of course work must be completed with a minimum of 12 hours at the 6000-level.

The total number of hours required for the Ph.D. degree in materials science and engineering is 72. Ph.D. students are required to complete the three core courses, MS&E 6110, MS&E 6120, and MS&E 6130. To advance to Ph.D. candidacy, the student must take and pass a qualifying exam. This must be completed prior to the beginning of the fifth semester after entering the graduate program. Students must also take and pass the comprehensive exam in accordance with Missouri S&T rules.

## Advanced Engineering Materials

Missouri University of Science and Technology offers a graduate certificate in Advanced Engineering Materials for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Advanced Engineering Materials Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

Students admitted to the Advanced Engineering Materials Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the Master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to begin the courses in the Advanced Engineering Materials Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Required Course:

MET ENG 5810	Principles Of Engineering Materials	3
Any three of the following courses:		
CER ENG 5230	Glass Science And Engineering	3
CER ENG 5310	Advanced Ceramic Processing	3
CER ENG 6230	Composite Materials	3
MS&E 5230	Energy Materials	3
MET ENG 5150	Introduction to Metal Additive Manufacturing	3
MET ENG 5330	Nonferrous Alloys	3

## Materials for Extreme Environments

Missouri University of Science and Technology offers a graduate certificate Materials for Extreme Environments for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate

program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Materials for Extreme Environments Certificate Program is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses (provided in the curriculum section). In order to receive a Graduate Certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

A student admitted to the Materials for Extreme Environments Certificate Program will have non-degree graduate status, however, they will earn graduate credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the Master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to begin the courses in the Materials for Extreme Environments Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Required Course:

MET ENG 5810	Principles Of Engineering Materials	3
Any three of the following courses:		
CER ENG 5250	Refractories	3
CER ENG 6230	Composite Materials	3
MS&E 5220	Advanced Phase Equilibria	3
MET ENG 5170	Nuclear Materials I	3
MET ENG 5310	Corrosion and Its Prevention	3
MECH ENG 5212	Introduction to Finite Element Analysis	3

**Laura Bartlett**, Associate Professor

PHD Missouri University of Science and Technology  
Melt processing and solidification phenomena, ferrous and non-ferrous casting, physical and mechanical metallurgy of irons and steels.

**Richard K Brow**, Curators Distinguished Professor

PHD Pennsylvania State University  
Physics and chemistry of inorganic glasses; spectroscopic characterization of glass structure; biomaterials; optical materials.

**Anthony Convertine**, Assistant Professor

PHD University of Southern Mississippi  
Biomaterials, drug delivery, polymers, and sol-gel ceramics.

**Fatih Dogan**, Professor

PHD Technical University of Berlin  
High temperature superconductors, solid oxide fuel cells, dielectrics, nanostructured electronic ceramics.

**Arezoo Emdadi**, Assistant Professor  
PHD Missouri University of Science and Technology  
Computational material science, applied mathematics, phase-field modeling, and fracture mechanics.

**William G Fahrenholtz**, Curators Distinguished Professor  
PHD University of New Mexico  
Thermodynamics, phase equilibria, reactive processing, ultra-high temperature ceramics.

**Yijia Gu**, Assistant Professor  
PHD Pennsylvania State University  
Additive manufacturing, computational material methods, and non-ferrous alloys.

**Gregory E Hilmas**, Curators Distinguished Professor and Department Chair  
PHD University of Michigan-Ann Arbor  
Microstructure-processing-mechanical property relationships in structural ceramics; novel processing techniques for the fabrication of ceramics and ceramic composites; biomaterials.

**Wayne Huebner**, Professor  
PHD University of Missouri-Rolla  
Structure-property relationships in ferroelectric, piezoelectric, and ionically-conducting materials.

**Aditya Kumar**, Assistant Professor  
PHD Ecole Polytechnique Federale de Lausanne (EPFL)  
Composition-structure-property relationships in cementitious, silicate, and aluminosilicate materials.

**Simon Lekakh**, Research Professor  
PHD Belorussian Polytechnic Institute  
Thermodynamics of liquid metals, solidification, metal casting and metallurgical processes.

**David Lipke**, Assistant Professor  
PHD Georgia Institute of Technology  
Composite materials, reaction processing, materials in extreme environments.

**F Scott Miller**, Teaching Professor  
PHD University of Missouri-Rolla  
Electron microscopy, materials characterization.

**Michael Scott Moats**, Professor  
PHD University of Arizona  
Extractive metallurgy, aqueous processing of metals, electrometallurgy.

**Joseph W Newkirk**, Professor  
PHD University of Virginia  
Advanced additive manufacturing, intermetallic alloys, alloys for corrosion and high temperature, powder metallurgy.

**Ronald J O'Malley**, Professor  
PHD Massachusetts Institute of Technology  
F. Kenneth Iverson Chair Professor of Steelmaking Technologies.

**Jeffrey D Smith**, Professor  
PHD University of Missouri-Rolla  
Thermochemistry and high temperature phase equilibria of condensed and non-condensed ceramic systems; chemical, mineralogical and microstructural analysis of refractory materials.

**David C Van Aken**, Professor Emeritus<sup>1</sup>  
PHD University of Illinois Urbana  
Thermal spraying, fatigue and fracture, rapid solidification, advanced alloy design, electron microscopy.

**Jeremy Lee Watts**, Associate Research Professor  
PHD Missouri S&T  
Structure property relations, ultra-high temperature ceramics, thermomechanical properties, additive manufacturing.

**Haiming Wen**, Assistant Professor  
PHD University of California-Davis  
Bulk nanostructured metals, high-entropy alloys, advanced microstructural characterization, nuclear materials.

**Kelley Wilkerson**, Assistant Teaching Professor  
PHD Missouri University of Science and Technology  
Refractory and high temperature research with additional interest in ceramic education and outreach.

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**MS&E 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MS&E 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**MS&E 5010 Seminar** (RSD 0.0-6.0)  
(Variable) Discussion of current topics.

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**MS&E 5040 Oral Examination** (IND 0.0)  
(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D students may be processed during intersession. Off-campus M.S. students must be enrolled in an oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MS&E 5060 Chemistry of Construction Materials** (LEC 3.0)  
The objective of the course is to utilize fundamental concepts of materials science and chemistry to understand, analyze, and describe the chemistry of construction materials. Special focus is given to describe composition-reactivity-microstructure-property relations in various cementitious materials. Prerequisites: At least Senior standing.

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**MS&E 5099 Research** (IND 0.0-15)  
(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MS&E 5210 Tissue Engineering** (LEC 3.0)  
The course will use problem-based case studies to introduce junior and senior undergraduate students to the principles and clinical applications of tissue engineering. Topics include the use of biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. Prerequisite: Junior or Senior standing. (Co-listed with Bio Sci 5240).

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**MS&E 5220 Advanced Phase Equilibria** (LEC 3.0)

Advanced aspects of unary, binary and ternary organic, phase equilibria. Includes practical examples of the applications of phase diagrams to solve engineering problems. Prerequisite: Graduate standing.

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**MS&E 5230 Energy Materials** (LEC 3.0)

The objectives of the course are to understand how the rational design and improvement of chemical and physical properties of materials can lead to energy alternatives that can compete with existing technologies. Discussions on the present and future energy needs from a view point of multidisciplinary scientific and technological approaches. Prerequisite: Senior standing.

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**MS&E 5310 Biomaterials I** (LEC 3.0)

This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisites: Senior undergraduate standing. (Co-listed with BIO SCI 5210, CHEM ENG 5200).

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**MS&E 5460 Molecular Engineering of Materials** (LEC 3.0)

This course focuses on the fundamentals of molecular engineering with an emphasis on their applications including renewable/clean energy solutions, energy storage, air/water cleaning, and optoelectronics. Topics include principles of modern physics, carbon chemistry, macromolecules, metal(covalent)-organic frameworks sol-gel processing and crystal growth. Prerequisites: Senior Standing or consent of instructor. (Co-listed with Chem 5460).

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**MS&E 5517 Materials Selection in Mechanical Design** (LEC 3.0)

This course will introduce the basics of materials selection in mechanical design. It will also introduce the benefits of computational materials and process selection. The students will also learn to use a commercially available materials selection software. This course will be offered as Distance Ed. Prerequisite: Met Eng 2110.

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**MS&E 5810 Introduction to Polymeric Materials** (LEC 3.0)

A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with Chem 5810).

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**MS&E 5819 Polymer Synthesis and Characterization Lab** (LAB 1.0)

Laboratory experiments dealing with polymerization syntheses and solution, bulk and solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Credit may not be given for both Chem 5819 and Chem 4819. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810 or Chem Eng 5310, preceded or accompanied by Chem 1100 or Chem 5100 or an equivalent training program approved by S&T. (Co-listed with Chem 5819).

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**MS&E 5850 Introduction to Coating Chemistry** (LEC 3.0)

Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Credit may not be given for both Chem 5850 and Chem 4850. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with Chem 5850).

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**MS&E 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MS&E 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MS&E 6010 Seminar** (RSD 0.0-6.0)

(Variable) Discussion of current topics.

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**MS&E 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MS&E 6060 Advanced Chemistry of Construction Materials** (LEC 3.0)

To describe fundamental composition-reactivity-microstructure-property relationships in construction materials. Tests will include quizzes, written-exams, as well as a term paper and a presentation on a topic relevant to the course.

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**MS&E 6085 Internship** (IND 0.0-15)

(Variable) Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**MS&E 6099 Research** (IND 0.0-15)

(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MS&E 6110 Bonding, Crystallography, and Structure-Property Relationships** (LEC 3.0)

Principles of electronic structure and chemical bonding in solids and their relationships to electrical, mechanical, thermal, and optical properties. An exploration of reciprocal lattices and tensor properties of crystals; consideration of the impact of crystal symmetry on anisotropy. The influence of defects and grain boundary phenomena on material behavior. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

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**MS&E 6120 Thermodynamics and Phase Equilibria** (LEC 3.0)

Classical thermodynamic treatment of materials and material processing based on the 1st and 2nd Laws of Thermodynamics and phase equilibria considerations. The course will cover equilibria in gaseous systems, gas-solid reactions including passive and active oxidation, solution thermodynamics, phase equilibria in solution systems, and electrochemistry. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

**MS&E 6130 Kinetic Theory for Materials** (LEC 3.0)

Phenomenological and atomistic theories of diffusion in materials including discussion of short circuit diffusion and ionic diffusion in an electric field. Fundamentals of phase transformation in materials; chemical fluctuation, nucleation and growth theory; kinetic models for evaluating and predicting diffusion controlled transformation kinetics. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

**MS&E 6210 Advanced Tissue Engineering** (LEC 3.0)

The course will introduce graduate students to the principles and clinical applications of tissue engineering including the use biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. A related topic term paper and oral presentation are expected. Prerequisite: Graduate standing. (Co-listed with Bio Sci 6240).

**MS&E 6220 Advanced Energy Materials** (LEC 3.0)

The objectives of the graduate level course are to review the recent developments on advanced energy materials and systems in addition to basic understanding how chemical and physical properties of materials can lead to energy alternatives. Prerequisite: Graduate standing.

**MS&E 6230 Nanomaterials** (LEC 3.0)

Introduction of the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Students will need to complete a project related to nanomaterials. Prerequisite: Graduate Standing. (Co-listed with Chem Eng 6310).

**MS&E 6310 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. (Co-listed with BIO SCI 6210, CHEM ENG 6300).

**MS&E 6460 Advanced Molecular Engineering of Materials** (LEC 3.0)

This advanced course focuses on the fundamentals of molecular science and engineering and their applications including renewable/clean energy solutions, energy storage, and optoelectronics. Topics include principles of carbon chemistry, macromolecules, metal(covalent)-organic frameworks, sol-gel processing, crystal growth and other advanced topics. Prerequisites: Graduate Standing or consent of instructor. (Co-listed with CHEM 6460).

**MS&E 6820 Polymer Synthesis** (LEC 3.0)

The methods of organic monomer and polymer syntheses will be explored. Mechanistic and structural components, modern and current industrial methods for polymer syntheses will be discussed. Topics include linear, branched, graft, and dendritic polymers, nano-technology and macromers. Prerequisites: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; Chem 2220 or Chem 4210 or Chem 4220 or Chem 5210 or Chem 5220. (Co-listed with Chem 6820).

**MS&E 6840 Polymer Physical Chemistry and Analysis** (LEC 3.0)

A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; thermodynamics. (Co-listed with Chem 6840).

## Mathematics and Statistics

The department of mathematics and statistics offers programs leading to the M.S. in applied mathematics, either with or without a thesis, the master of science for teachers degree, and the Ph.D. in Mathematics. The M.S. in applied mathematics can be pursued with either a mathematics or a statistics emphasis, while the Ph.D. in mathematics can be pursued with an emphasis in mathematics, computational and applied mathematics, or statistics. The M.S. is recommended, but not required, as a prerequisite for the Ph.D. If you intend to pursue the doctorate without obtaining a master's degree, during the first two academic years you are required to obtain at least 32 hours of graduate credit, with emphasis placed on subject areas that will provide you with a solid foundation in mathematics and/or statistics relevant to your chosen emphasis area. Specifically, these hours should be selected so that you will have obtained an introduction to (a) modern algebra, analysis, statistics and topology if selecting the mathematics emphasis, (b) real analysis, differential equations, partial differential equations, statistics as well as either complex analysis or modern algebra if choosing the computational and applied mathematics emphasis, and (c) linear algebra, probability, and statistical inference, if choosing the statistics emphasis.

The mathematics and statistics department also offers graduate certificates in actuarial science, statistical methods in psychology, and statistics.

Fellowships and graduate assistantships are available to qualified applicants. Detailed information about these opportunities may be obtained from the department chair or the director of graduate studies. Additional information is available electronically at: <http://math.mst.edu/>.

The department faculty and graduate students, along with graduate instruction and research activities, are housed in the Rolla Building. The Rolla Building, erected 1871, was the original home of the University of Missouri School of Mines and Metallurgy.

The program for the M.S. in Applied Mathematics without a thesis must include at least 30 hours of graduate credit, with the following additional specifications:

- At least 18 hours must come from Mathematics & Statistics Department lecture courses at the 5000-level or higher.
- At least 6 of the 18 hours must come from Mathematics & Statistics Department lecture courses at the 6000-level.



- A minimum of 3 additional hours must come from 6000-level lecture courses.

The program for the M.S. in Applied Mathematics with a thesis must include at least 30 hours of graduate credit, with the following additional specifications:

- At least 12 hours must come from Mathematics & Statistics Department lecture courses at the 5000-level or higher.
- At least 6 of the 12 hours must come from Mathematics & Statistics Department lecture courses at the 6000-level.
- At least 6 hours of Graduate Research (MATH 5099, MATH 6099, STAT 5099, or STAT 6099) must be completed.
- Candidates must pass an oral thesis defense.

All M.S. candidates are encouraged to include in their program courses in engineering or science that are closely related to their interests. For those intending to terminate study at the M.S. level, specializations supporting specific career goals are possible.

The master of science for teachers program is primarily designed for secondary school teachers in the physical sciences and mathematics. The program of study must include at least 30 hours of courses numbered at the 4000-level or above in science and mathematics, three hours of which must be at the 6000-level. A student may substitute up to six credit hours of coursework at the 3000 level in place of six hours of 4000 level courses; any such courses must be from departments other than mathematics and statistics and are subject to the approval of the student's master's committee.

A program for the Ph.D. degree includes about 30 hours of breadth in graduate level mathematics and statistics, about 30 hours of courses in or outside of the department representing a field of specialization, and a minimum of 30 hours devoted to the dissertation. In particular, the Ph.D. requires a total of at least 30 hours of Math/Stat 6099. Math/Stat 6099 hours used to complete an M.S. thesis cannot be counted toward the doctoral research requirements.

The specific program for a candidate is designed jointly by the candidate and the candidate's advisory committee. A qualifying examination, usually taken soon after completion of the M.S. degree or equivalent course work, is required. For those obtaining a doctoral degree with emphasis in Mathematics a reading knowledge of one modern foreign language, typically either French, German, or Russian, is required. Those whose doctoral emphasis is computational and applied mathematics, statistics, knowledge in a programming language such as C, C++, or FORTRAN and programming expertise demonstrated through an approved project is required. At times approved by the advisory committee, candidates must pass both written and oral comprehensive examinations. These examinations may cover courses outside the department. The dissertation is expected to represent original research and to meet the standard ordinarily required for publication in one of the journals devoted to reporting research in the selected field.

Graduate certificates are offered in the following:

Actuarial Science

Statistical Methods in Psychology

Statistics

**Akim Mouhamadou Adekpedjou**, Associate Professor  
PHD University of South Carolina Columbia  
Recurrent event data analysis, stochastic processes, survival analysis.

**Elvan Akin**, Professor  
PHD University of Nebraska Lincoln  
Dynamic equations on time scales, differential equations, difference equations, oscillation, boundary value problems.

**Martin Bohner**, Curators' Distinguished Professor  
PHD University of Ulm, Germany  
Ordinary differential equations, dynamic equations on time scales, difference equations, Hamiltonian systems, variational analysis, boundary value problems, control theory, oscillation.

**Wlodzimierz Jan Charatonik**, Professor  
PHD University of Warsaw, Poland  
Topology, continuum theory, hyperspaces, inverse limits.

**Stephen L Clark**, Professor  
PHD Univ. of Tennessee-Knoxville  
Differential and difference equations, operator theory, direct and inverse spectral theory, inequalities.

**David E Grow**, Associate Professor  
PHD University of Nebraska Lincoln  
Analysis, Fourier analysis, lacunary series.

**Daozhi Han**, Assistant Professor  
PHD Florida State University  
Applied analysis of PDE's, numerical analysis and computation, fluid dynamics.

**Xiaoming He**, Associate Professor  
PHD Virginia Polytechnic Institute  
Finite elements, Interface problems, numerical methods for partial differential equations, computational fluid dynamics, computational electromagnetism, stochastic partial differential equations, extrapolations, boundary integral equations, feedback control.

**Wenqing Hu**, Assistant Professor  
PHD University of Maryland-College Park  
Stochastic analysis, stochastic differential equations, random dynamical systems, (stochastic) partial differential equations.

**Eugene M Insall Jr**, Associate Professor  
PHD University of Houston  
Logic, nonstandard methods, nonstandard models, algebra, topological algebra, topological model theory

**Nan Jiang**, Assistant Professor  
PHD University of Pittsburgh  
Numerical methods for partial differential equations, numerical analysis, computational fluid dynamics turbulence modeling.

**Vy Khoi Le**, Professor  
PHD University of Utah  
Nonlinear differential equations, bifurcation, calculus of variations.

**Jason Murphy**, Assistant Professor  
PHD University of California-Los Angeles  
Harmonic analysis and nonlinear dispersive PDE's.

**Gayla Renee Olbricht**, Associate Professor  
PHD Purdue University  
Statistical genomics and epigenomics, hidden Markov models, modeling dependent data, mixed models.

**Robert L Paige**, Professor  
PHD Colorado State University  
Statistical shape analysis.

**Robert Paul Roe**, Associate Professor  
PHD University of Wyoming  
Chaotic dynamical systems, topological dynamics, geometric topology, geometric analysis.

**V A Samaranyake**, Curators' Distinguished Teaching Professor  
PHD Kansas State University  
Reliability, time series analysis, statistical applications in biology, economics, and engineering.

**John R Singler**, Associate Professor  
PHD Virginia Polytechnic Institute  
Computational methods for reduced order modeling, control and sensitivity analysis of partial differential equations, numerical analysis, applied mathematics, fluid dynamics.

**Xuerong (Meggie) Wen**, Associate Professor  
PHD University of Minnesota  
Nonlinear and nonparametric regression, regression graphics, computational statistics and statistical genetics, with an emphasis on sufficient dimension reduction in the context of regression.

**Yanzhi Zhang**, Associate Professor  
PHD National University of Singapore  
Multiscale modeling and simulations in material science, optimal control problems in superconductivity and superfluidity, Bose-Einstein condensation, quantized vortex dynamics, numerical algorithms for partial differential equations.

**MATH 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MATH 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**MATH 5010 Graduate Seminar** (SEM 1.0)  
Discussion of advanced or current topics.

**MATH 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**MATH 5099 Graduate Research** (IND 0.0-6.0)  
Investigation of an advanced nature leading to the preparation of a MS thesis or dissertation.

**MATH 5105 Modern Algebra I** (LEC 3.0)  
Equivalence relations and functions, basic properties of groups, subgroups, permutations, cosets and Lagrange's Theorem, homomorphisms and isomorphisms, factor groups. Prerequisite: Math 3109 or graduate standing; preceded or accompanied by Math 3108.

**MATH 5106 Modern Algebra II** (LEC 3.0)  
This course is a continuation of Math 5105. Rings and fields are discussed. Euclidean domains, principal ideal domains, unique factorization domains, vector spaces, finite fields and field extensions are studied. Prerequisite: Math 5105.

**MATH 5107 Combinatorics And Graph Theory** (LEC 3.0)  
Covers some basics of enumeration and graph theory. Topics are selected from the following: permutations combinations, the inclusion/exclusion principle, generating functions, recurrence relations, trees, networks, graph connectivity and graph coloring. Prerequisite: Comp Sci 1200 or Math 3109.

**MATH 5108 Linear Algebra II** (LEC 3.0)  
Eigenvalue problems, Cayley-Hamilton theorem, Jordan normal form, linear functionals, bilinear forms, quadratic forms, orthogonal and unitary transformations, selected applications of linear algebra. Prerequisite: Math 3108.

**MATH 5154 Mathematical Logic I** (LEC 3.0)  
A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Comp Eng 5803, Comp Sci 5203 and Philos 4354).

**MATH 5215 Introduction To Real Analysis** (LEC 3.0)  
Riemann-Stieltjes integration, sequences and series of functions, uniform approximation, the Banach Space  $C(a,b)$ , Lebesgue measure and integration, the space  $LP(a,b)$ , Fourier series. Prerequisite: Math 4209.

**MATH 5222 Vector And Tensor Analysis** (LEC 3.0)  
Vector algebra, vector differential and integral calculus, line and surface integrals, theorems of Stokes and Gauss, tensor algebra and tensor analysis, applications to problems in kinematics, elasticity theory, fluid mechanics, electromagnetic theory, relativity theory. Prerequisite: Math 2222; Math 3103 or Math 3108.

**MATH 5302 Intermediate Differential Equations** (LEC 3.0)  
Linear differential equations, vector-matrix systems, existence and uniqueness theory, nonlinear systems, phase-plane analysis, introduction to stability theory. Prerequisite: Math 3304 or Math 3329.

**MATH 5325 Partial Differential Equations** (LEC 3.0)

Linear equations, heat equation, eigenfunction expansions, Green's formula, inhomogeneous problems, Fourier series, wave equation. Prerequisite: Math 3304 with a grade of "C" or better.

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**MATH 5351 Introduction To Complex Variables** (LEC 3.0)

The basic tools of complex variables are studied. These include the Cauchy-Riemann equations, complex contour integration, the Cauchy-Goursat theorem, conformal mappings, the calculus of residues and applications to boundary value problems. Prerequisite: Math 3304.

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**MATH 5483 Operational Calculus** (LEC 3.0)

The Laplace transformation, properties of the transformation, various applications to ordinary and partial differential equations, systems with step and Dirac functions as driving forces, various non-elementary functions and their transforms, problems in heat conduction and wave motion, Fourier transforms and their operational properties. Prerequisite: Math 3304.

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**MATH 5512 Introduction To Differential Geometry** (LEC 3.0)

Elements of the geometry of curves and surfaces in Euclidean three-space using methods of advanced calculus and vectors. Prerequisite: Math 4209 or Math 5222.

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**MATH 5530 Topics in Geometry - Graduate Option** (LEC 3.0)

A survey of non-Euclidean geometries, finite geometries, affine and projective planes, metric postulates for the Euclidean plane, and selected topics. Students will demonstrate graduate-level mastery of the subject matter. Credit will not be given for both Math 4530 and Math 5530. Prerequisites: MATH 3108.

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**MATH 5585 Introduction To Topology** (LEC 3.0)

Metric spaces; general topological spaces; connectedness, compactness, separation properties, functions and continuity. Prerequisite: Math 4209.

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**MATH 5603 Methods of Applied Mathematics** (LEC 3.0)

Methods to develop and analyze mathematical models. Topics include dimensional analysis and scaling, perturbation methods, and the construction of ordinary and partial differential equation models. Prerequisites: Math 3304 or 3329 with a grade of "C" or better, programming competency.

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**MATH 5604 Introduction to Numerical Methods for Differential Equations** (LEC 3.0)

An introduction to finite difference methods for ordinary and partial differential equations, including (1) the derivation of the numerical methods, (2) implementation of the methods in Matlab, and (3) the mathematical accuracy and stability analysis of the methods. Prerequisites: MATH 3304 and programming competency (preferably Matlab).

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**MATH 5737 Financial Mathematics** (LEC 3.0)

The course objective is to provide an understanding of the fundamental concepts of financial mathematics. Topics include pricing, assets-liability management, capital budgeting, valuing cash flow, bonds, futures, swaps, options. Preparation for the financial mathematics actuarial exam will be provided. Prerequisites: Math 1215 or Math 1221, Econ 1100 or Econ 1200, and one of the following: Stat 3111, Stat 3113, Stat 3115, Stat 3117 or Stat 5643. (Co-listed with Econ 5337).

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**MATH 5940 Mathematical Analysis For Secondary Teachers** (LEC 3.0)

Designed to help teachers gain a deeper understanding of the fundamental idea in analysis, that of a limit. A discovery method is used which includes both individual and group work. Students will present their results in written and oral format. Prerequisite: Math 2222 or equivalent.

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**MATH 5948 Mathematical Analysis For Secondary Teachers Practicum** (LEC 1.0)

An instructional unit based on the discovery method used in Math 340 will be designed by each student. These units will be class tested. The unit and results of class testing will be presented both in written and oral format. Prerequisite: Math 5940.

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**MATH 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MATH 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MATH 6010 Graduate Seminar** (RSD 1.0-3.0)

Discussion of topics of current interest. Prerequisite: Graduate standing.

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**MATH 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MATH 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MATH 6099 Research** (IND 0.0-15)

Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

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**MATH 6105 Finite Fields And Applications** (LEC 3.0)

After reviewing basic group theory and introducing basic properties of commutative rings, the main focus of the course will be on topics such as structure of finite fields, polynomials over finite fields, and applications such as coding theory and cryptography. Prerequisite: Math 5105.

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**MATH 6106 Introduction to Ring Theory** (LEC 3.0)

Properties of rings with an emphasis on commutative rings. Ideals, factor rings, ring homomorphisms, polynomial rings; factorization, divisibility, and irreducibility. Introduction to extension fields and Galois theory. Applications may be chosen based on the interests of the students. Prerequisite: Math 5105.

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**MATH 6107 Group Theory** (LEC 3.0)

Groups, subgroups, and factor groups; homomorphisms, isomorphisms, and associated theorems; abelian groups; Sylow theorems and p-groups; permutation groups; free groups and generators; representation theory; cohomology theory. Prerequisite: Math 5106.

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**MATH 6108 Applied Matrix Theory** (LEC 3.0)

A second course in matrix theory directed toward applications. Linear spaces, linear operators, equivalence and similarity, spectral theorem, canonical forms, congruence, inertia theorem, quadratic forms, singular value decomposition and other factorizations, generalized inverses. Applications to optimization, differential equations, stability. Prerequisites: Math 3103, 3108, or 5302.

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**MATH 6215 Functions Of A Real Variable I** (LEC 3.0)

Measure spaces, extensions of measures, probability spaces, measures and distributions in normed linear spaces, product measures, independence, integral and expectation, convergence theorems, Radon-Nikodym theorem and applications. Lp spaces, selected topics. Prerequisite: Math 5215.

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**MATH 6216 Functions Of A Real Variable II** (LEC 3.0)

Abstract measures and integrals, the Daniell integration theory, integration on locally compact Hausdorff spaces, integration in function spaces, selected topics. Prerequisite: Must be preceded by Math 6215.

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**MATH 6330 Theory Of Differential Equations I** (LEC 3.0)

Stability theory, Liapunov's direct method, periodic solutions, Poincare-Bendixson theory, applications. Prerequisite: Math 5302.

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**MATH 6331 Theory Of Differential Equations II** (LEC 3.0)

Continuation of Math 6330. Nonlinear oscillations, solutions near singular points, asymptotic methods, differential equations on manifolds, boundary-value problems. Prerequisite: Math 5302.

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**MATH 6351 Functions Of A Complex Variable I** (LEC 3.0)

Complex plane, complex function theory, elementary Riemann surfaces, conformal mapping, complex integration, infinite complex series and sequences, calculus of residues with applications. Prerequisite: Math 4211.

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**MATH 6352 Functions Of A Complex Variable II** (LEC 3.0)

Argument principle and consequences; harmonic functions and Dirichlet's problem; infinite products; entire, meromorphic and rational functions; analytic continuation; symmetry principle; conformal mapping; functions of several complex variables. Prerequisite: Preceded by Math 6351.

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**MATH 6375 Theory Of Partial Differential Equations** (LEC 3.0)

Sobolev spaces; existence, uniqueness, and regularity of weak solutions to linear elliptic, parabolic, and hyperbolic PDEs; selected topics. Prerequisite: Math 6417.

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**MATH 6383 Special Functions** (LEC 3.0)

Infinite products, gamma and beta functions, asymptotic series, the hypergeometric function, generalized hypergeometric functions, Bessel functions, generating functions; polynomials of Legendre, Hermite, Laguerre, and Jacobi; elliptic functions, theta functions, Jacobian elliptic functions. Prerequisites: Math 4209 and 5351.

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**MATH 6417 Functional Analysis I** (LEC 3.0)

Banach spaces, Hilbert spaces, linear transformations, Hahn-Banach theorem, duality, uniform boundedness principle, weak topologies, convexity, bounded linear maps, compact operators, and spectral theory. Prerequisites: Math 5215; Math 5108 or Math 5585.

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**MATH 6418 Functional Analysis II** (LEC 3.0)

A continuation of Math 6417 with additional topics related to bounded and unbounded operators and their applications. Prerequisites: Math 6215 and Math 6417.

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**MATH 6461 Harmonic Analysis I** (LEC 3.0)

Fourier series, norm and pointwise convergence of Fourier series, the conjugate and maximal functions, analytic functions in the unit disk and Hardy spaces, interpolation of linear operators and the Hausdorff-Young-Riesz Theorem, Sidon sets. Prerequisites: Math 5215 and Math 5351.

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**MATH 6462 Harmonic Analysis II** (LEC 3.0)

Fourier integrals, almost-periodic functions on the real line, Banach algebras, Wiener's Tauberian Theorem and the prime number theorem, the Paley-Wiener Theorems, band-limited functions and Shannon's Theorem, the continuous wavelet transform, discrete wavelet transforms and frames, orthonormal bases of wavelets and multi-resolution analysis. Prerequisite: Must be preceded by Math 6461.

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**MATH 6540 Geometric Structures** (LEC 3.0)

Selected topics in non-Euclidean, solid, projective, and fractal geometry. Prerequisite: Math 4530.

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**MATH 6548 Geometric Structures Practicum** (LEC 1.0)

An instructional unit based on material learned in Math 6540 will be designed by each student. These units will be class tested. The unit and results of class testing will be presented both in written and oral format. Prerequisite: Math 6540.

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**MATH 6585 Topology I** (LEC 3.0)

Topological spaces, uniform and quasi-uniform spaces, product and quotient spaces, separation properties and connected spaces, compactness. Prerequisite: Math 5585.

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**MATH 6586 Topology II** (LEC 3.0)

Metrizability conditions, the theory of convergence using both filters and nets, completions and compactifications, and papers from the recent literature. Prerequisite: Math 6585.

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**MATH 6601 Numerical Analysis** (LEC 3.0)

A proof based course emphasizing theoretical analysis of convergence and accuracy of various numerical methods including approximate solutions of linear and nonlinear equations, numerical integration, and function approximation, with implementation to validate results and illustrate the methods. Prerequisites: Any 4000 or higher level MATH course, or any instructor approved 4000 or higher level course from another discipline with a significant computational component.

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**MATH 6602 Mathematical Foundation of Finite Element Methods** (LEC 3.0)

Implementation and theoretical analysis of the finite element method for the approximate solution of partial differential equations. Implementation of finite element methods for elliptic and parabolic equations. Theoretical analysis of convergence, accuracy, and stability of approximate solutions. Prerequisites: Any 4000 or higher level Mathematics course, or any instructor approved 4000 or higher level course from another discipline with a significant computational component.

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**MATH 6665 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Eng Mgt 6412 and Sys Eng 6412).

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**MATH 6737 Financial Mathematics II** (LEC 3.0)

Continuation of Math 5737/Econ 5337. Topics include martingales and measures, stopping times, discrete and continuous time finance, Brownian motion, Ito calculus, stochastic differential equations, Black-Scholes-Merton formula, numerical procedures. Prerequisite: Math 5737 or Econ 5337. (Co-listed with Econ 6337).

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**MATH 6802 Mathematical Physics I** (LEC 3.0)

Vector spaces, generalized coordinate transformations, vector analysis, tensors, partial differential equations in physics and boundary value problems, orthogonal functions and solutions to ordinary differential equations, hypergeometric, confluent hypergeometric, Legendre, Laguerre, and Bessel functions, Hermite polynomials, Green's functions in one dimension. (Co-listed with Physics 6403).

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**MATH 6803 Mathematical Physics II** (LEC 3.0)

Green's functions in three dimensions, integral equations, complex variable theory and contour integration, group theory with applications to quantum mechanics, solid state and molecular physics. Prerequisite: Math 6802 or Physics 6403. (Co-listed with Physics 6413).

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**STAT 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**STAT 5001 Special Topics** (IND 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**STAT 5099 Graduate Research** (IND 0.0-6.0)

Investigation of an advanced nature leading to the preparation of a MS thesis or dissertation.

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**STAT 5260 Statistical Data Analysis Using SAS** (LEC 2.0 and LAB 1.0)

This course will introduce the student to selected data analytic tools implemented in the Statistical Analysis System (SAS) and appropriate and effective use of these tools. Focus would be on both the use of SAS data analytic tools and the theoretical and methodological rationale that form the basis of such analyses. Prerequisite: One of Stat 3113 or 3115 or 3117 or 5643; and one of Stat 5346 or 5353 or 6841 or 6343 or 6344 or 6545.

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**STAT 5346 Regression Analysis** (LEC 3.0)

Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 2222 and one of Stat 3111, 3113, 3115, 3117, or 5643. (Co-listed with Comp Sci 5204).

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**STAT 5353 Statistical Data Analysis** (LEC 3.0)

Introduction to methods for analyzing statistical data from experiments and Introduction to methods for analyzing statistical data from experiments and surveys. Analysis of variance, correlation, introduction to regression techniques, contingency tables, non-parametric techniques and introduction to modern statistical software. Prerequisites: Math 2222 and one of Stat 1115, 3113, 3115 and 3117.

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**STAT 5425H Introduction to Biostatistics-Honors** (LAB 1.0 and LEC 3.0)**STAT 5643 Probability And Statistics** (LEC 3.0)

Introduction to the theory of probability and its applications, sample spaces, random variables, binomial, Poisson, normal distributions, derived distributions, and moment generating functions. Prerequisite: Math 2222.

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**STAT 5644 Mathematical Statistics** (LEC 3.0)

A continuation of Stat 5643 with introduction to the theories of point estimation, hypothesis testing, and interval estimation. Includes sufficiency, completeness, likelihood and how they apply to the exponential family. Prerequisite: Stat 5643.

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**STAT 5755 Statistical Models in Actuarial Science** (LEC 3.0)

This course covers the statistical foundation of actuarial models and their applications. Topics include survival and severity models, Kaplan-Meier and Nelson-Aalen estimators, aggregate and credibility models for insurance losses, discrete time Markov chains, ruin theory, and simulation. Prerequisite: Stat 5643 and either Stat 5644 or a 3000-level Stat course. (Co-listed with Econ 4350).

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**STAT 5756 Statistical Models for Life Contingencies** (LEC 3.0)

The basic statistical theory of actuarial models for life uncertainties such as time of death. Multiple life and multiple decrement models, statistical models for life and contingent insurance; last survivor, disability, withdrawal, retirement and reserving models for life insurance. Prerequisite: Stat 5643.

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**STAT 5756H Stat Models for Life Cont-Honors** (LEC 3.0)**STAT 5814 Applied Time Series Analysis** (LEC 3.0)

Introduction to time series modeling of empirical data observed over time. Topics include stationary processes, autocovariance functions, moving average, autoregressive, ARIMA, and GARCH models, spectral analysis, confidence intervals, forecasting, and forecast error. Prerequisites: One of Stat 3113, 3115, 3117, 5643 and one of Math 3103, 3108, or 5108.

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**STAT 5904 Science Education and Quantitative Literacy for Middle School Teachers** (LEC 3.0)

An integrated science-mathematics course for middle school teachers. Course covers selected science/mathematics topics/skills specified in Missouri standards for grades 5-7. Inquiry based methods of teaching these topics in an integrated manner will be emphasized. Prerequisite: Current enrollment in a Teacher Education Program or a full or part-time teacher in a K-12 school. (Co-listed with Physics 4625).

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**STAT 5905 Making Sense Of Data For Elementary School Teachers** (LEC 3.0)

An activity based course that is intended to provide elementary school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint. Prerequisite: Graduate Standing.

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**STAT 5906 Making Sense Of Data For Middle School Teachers** (LEC 3.0)

An activity based course that is intended to provide middle school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

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**STAT 5907 Making Sense Of Data For High School Teachers** (LEC 3.0)

An activity based course that is intended to provide high school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

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**STAT 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects in the department. Consent of instructor required.

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**STAT 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**STAT 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**STAT 6050 Continuous Registration** (LEC 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**STAT 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**STAT 6238 Stochastic Optimization** (LEC 3.0)

Introduction to stochastic modeling theory and application. Topics include probability theory, Markov processes, renewal theory, and queuing theory. Additional topics include stochastic dynamic programming and stochastic programming. Prerequisite: Eng Mgt 5412. (Co-listed with Eng Mgt 6414).

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**STAT 6239 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Sys Eng 6214 and Comp Sci 6405).

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**STAT 6342 Categorical Data Analysis** (LEC 3.0)

A graduate-level introduction to statistical methods for analyzing categorical data. The topics include: contingency tables, generalized linear models including logistic regression models, log-linear models, ordinal and nominal regression models, Poisson regression, etc. The course will involve practical applications of the ideas and their implementations. Prerequisites: Stat 5644 and one of Stat 5346, Stat 5353, Stat 6344, or Stat 6553.

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**STAT 6343 Nonparametric Statistical Methods** (LEC 3.0)

A course covering distribution free statistical methods. Topics include: order statistics, tests of hypotheses for one-sample and two-sample problems, analyses of variance, goodness-of-fit tests, runs test, independence and regression problems, point and interval estimation, ARE. Prerequisite: Stat 5644.

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**STAT 6344 Design And Analysis Of Experiments** (LEC 3.0)

Experimental designs and their statistical analysis. Includes completely randomized designs, complete and incomplete blocking designs, factorial and fractional factorial experiments, multiple comparisons, response surface analysis. Prerequisites: One of Stat 5353, Eng Mgt 5715 and one of Stat 3111, 3113, 3115, 3117, 5643; or Stat 5643 and one of Stat 3111, 3113, 3115, 3117.

**STAT 6545 Multivariate Statistical Methods** (LEC 3.0)

Analysis of data consisting of simultaneous measurements on many variables. Multivariate normal distribution, multivariate analysis of variance, canonical correlation, principal components, classification and clustering techniques. Prerequisites: Stat 5644 and Math 3103.

**STAT 6553 Linear Statistical Models I** (LEC 3.0)

Includes a development of the theory of the distribution of quadratic forms, and the estimation of parameters and testing hypotheses in linear statistical models. Prerequisites: Math 3108 and Stat 5643 and either Stat 5353 or 5644.

**STAT 6554 Linear Statistical Models II** (LEC 3.0)

Includes the theory of polynomial models, regression models, experimental design models, incomplete block models, nonlinear models, with emphasis on optimum properties of point and interval estimation and the power of tests. Prerequisite: Stat 6553.

**STAT 6570 Theory Of Reliability** (LEC 3.0)

Statistical analyses of life-testing distributions such as the Weibull, gamma, exponential, logistic, and normal. Reliability estimation, tolerance limits, censored sampling, and applications of Monte-Carlo simulation. Prerequisite: Stat 5644.

**STAT 6657 Advanced Mathematical Statistics I** (LEC 3.0)

The theory of estimation and hypothesis testing. Completeness and sufficiency. Maximum likelihood, minimax, Bayesian and invariant procedures for testing. Sequential decision rules. Emphasis on estimation. Prerequisites: Stat 5644 and Math 5215.

**STAT 6658 Advanced Mathematical Statistics II** (LEC 3.0)

A continuation of Stat 6657 with the emphasis on hypothesis testing. Prerequisite: Stat 6657.

**STAT 6814 Statistical Time Series Analysis** (LEC 3.0)

A formal introduction to the fundamentals of statistical modeling and analysis of discrete time series. Topics include autoregressive and moving average processes, ARMA models, second order stationarity, vector processes, autocorrelation function, Fourier representation, estimation and prediction of time series. Prerequisites: Stat 5643 and Math 3103 or 3108.

**STAT 6841 Stochastic Processes** (LEC 3.0)

Development and application of Poisson and nonhomogeneous Poisson processes; renewal processes; Markov chains and processes including birth and death processes; and normal processes, including Brownian motion. Prerequisites: Stat 5643 and Math 3304 or 3329.

**STAT 6846 Advanced Probability Theory** (LEC 3.0)

Probability spaces, random variables, distribution functions, expectations, independence, convergence theorems, characteristic functions, moment generating functions, and central limit theorem. Prerequisites: Stat 5644 and Math 5215.

## Mechanical Engineering

The mechanical engineering program in the department of mechanical and aerospace engineering offers comprehensive graduate education in a number of areas. The principal areas include: dynamics and controls; manufacturing; materials and structures; mechanical design; and thermal and fluid systems. A wide variety of interdisciplinary programs meeting specific objectives are available. The mechanical engineering program offers the master of science, doctor of philosophy, and direct doctor of philosophy degrees. The department also offers several graduate certificate programs in both aerospace engineering and mechanical engineering.

The mechanical and aerospace engineering department has many well-equipped laboratories located on the main campus, and a subsonic-flow laboratory in an off-campus facility. Some of the specially equipped laboratories on campus include: aerospace flow laboratory; advanced machining laboratory, augmented reality laboratory, composite materials manufacturing and characterization laboratory, computational radiative transfer laboratory, convection heat transfer laboratory, electromechanical transducer development laboratory, environmental control group laboratory, fluid dynamics and combustion laboratories, internal combustion engine and spray laboratories, laboratory for industrial automation and flexible manufacturing, laser-based manufacturing laboratory, rapid prototyping laboratory, radiative heat transfer laboratory, robotics laboratory, structural health monitoring laboratory and welding laboratory.

Some examples of research areas a candidate could specialize in are: acoustics; biomechanics; combustion and I. C. engines; computational fluid dynamics; computer-aided design; design methodology; dynamics and controls; heating, ventilation and air-conditioning (environmental control); heat transfer; laser-aided manufacturing; manufacturing and machining processes; materials and structures; mechanisms and robotics; mechatronics; micro-electromechanical systems (MEMS); thermal-fluid and energy systems; tribology; virtual reality and rapid prototyping.

The master of science thesis program consists of a minimum of 30 credit hours, including the following requirements: at least 21 credit hours of lecture courses, at least 6 credit hours of MECH ENG 6099, at least 9 credit hours of lecture courses in the MAE department (of which at least 3 credit hours must be at the 6000-level), at least 3 credit hours of mathematics, statistics, or computer science (AERO ENG 5830/MECH ENG 5830 Applied Computational Methods may be used to satisfy this requirement), and at least 6 credit hours of 6000-level lecture courses. A master of science non-thesis program consists of a minimum of 30 credit hours, including the following requirements: at least 24 credit hours in the MAE department and at least 9 credit hours of 6000-level lecture courses (of which at least 6 credit hours must be in the MAE department). Note that no course below the 5000-level may be applied to the degree requirements.

A student pursuing the doctor of philosophy degree normally follows a program of 90 semester hours beyond the B.S. degree or 60 semester hours beyond the M.S. degree. For those with M.S. degree, the 60 hours will consist of 24 hours of course work and 36 hours of thesis research. The Ph.D. course work must satisfy the departmental core course requirements for the M.S. degree. For the 24 hours of course work, a minimum of 12 hours must be completed within the department and at least three credit hours of mathematics/statistics. At least nine credit hours of course work must be at the 6000-level in the major field of study. In addition to these course requirements, a candidate must prepare a dissertation based on analytical and/or experimental research in a major area. This research must be equivalent to a minimum of 36 hours beyond the M.S. degree. There are no foreign language requirements for the master of science, doctor of engineering and doctor of philosophy degrees in mechanical engineering. However, a reading knowledge of one foreign language, German, French or Russian, may be required for the doctor of philosophy degree if the candidate's advisory committee feels that it is necessary.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The qualifying examination consists of taking a minimum of nine credit hours of approved graduate course work at the 5000- and 6000-level, including six hours in the major field, of which three hours must be at the 6000-level, and three hours of mathematics/statistics. To pass the qualifying examination, a student must have obtained a grade of B or better for all the courses with a GPA of at least 3.25.

A student holding a B.S. degree and pursuing the direct doctor of philosophy degree must complete at least 90 total credit hours, including the following requirements: at least 45 credit hours of lecture courses, at least 45 credit hours of MECH ENG 6099, at least 21 credit hours of course work in the MAE department, at least 6 credit hours of mathematics, statistics, or computer science (AERO ENG 5830/MECH ENG 5830 Applied Computational Methods may be used to satisfy three credit hours of this requirement), and at least 15 credit hours of 6000-level courses (of which at least 9 credit hours must be in the MAE department). In addition to these course requirements, a candidate must prepare a dissertation based on analytical, numerical, and/or experimental research. Note that no course below the 5000-level may be applied to the degree requirements.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The candidate is considered to have passed the qualifying examination if the candidate has taken at least four courses and has a GPA  $\geq 3.5$  at the end of the candidate's fourth semester. At least two courses must be in the MAE department, one of which must be at the 6000-level.

A candidate for the degree of doctor of engineering must complete the equivalent of three years (six semesters) of full-time work beyond the bachelor's degree for a total of at least 90 semester hours. The six semesters must include a minimum of two semesters in residence at Missouri S&T with a graduate registration of at least 12 hours per semester. At least two semesters above the M.S. must be in residence at Missouri S&T with a registration of at least six hours per semester. The course work must be directed toward two major engineering areas plus one area from the physical sciences, mathematics, or another field of engineering. In addition, a non-technical group of courses of 9 to 12 hours is required. The formal course work is expected to consist of at least 65 hours (the average is 72 hours). In addition to the formal course work, the candidate is expected to complete an internship with an industrial organization. This internship will consist of a minimum of one year of planned and approved high-level engineering experience. At the end of the

internship period, the candidate will prepare a dissertation which will earn from 18 to 25 hours credit and will be included in the total of 90 hours for the degree of doctor of engineering.

A candidate for the degree of doctor of philosophy must pass a qualifying examination. The candidate is considered to have passed the qualifying examination if the candidate has taken at least four courses and has a GPA  $\geq 3.5$  at the end of the candidate's fourth semester. At least two courses must be in the MAE department, one of which must be at the 6000-level. The candidate must also pass a comprehensive examination and a final examination, which consists of the dissertation defense. These examinations are conducted according to the rules of the graduate faculty and the department. The graduate faculty has residency requirements which must be satisfied by all doctoral students.

The mechanical and aerospace engineering department offers five graduate certificate programs. The certificate program consists of a four-course sequence from existing graduate-level courses. The graduate certificate program is available to all individuals holding a B.S. degree in an appropriate engineering discipline who have a minimum of two years of professional experience or are currently accepted into a graduate degree program in the mechanical and aerospace engineering department. While the students admitted to the certificate program will have non-matriculated status, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program if they so choose. The certificate credits taken by students admitted to the M.S. program will count toward their master's degrees. Currently, most classes offered in the graduate certificate are offered over the internet.

## Composite Materials and Structures

Students enrolled in this graduate certificate program will take three required courses and one elective course offered by the mechanical and aerospace engineering graduate degree programs. Alternative courses may be substituted with the departmental approval dependent on the availability of the courses listed below:

Required courses:

MECH ENG 5236/ AERO ENG 5236	Fracture Mechanics
MECH ENG 5282/ AERO ENG 5282	Introduction to Composite Materials & Structures
MECH ENG 6284/ AERO ENG 6284	Analysis of Laminated Composite Structures

Choose one of the following:

MECH ENG 5212/ AERO ENG 5212	Introduction to Finite Element Analysis
MECH ENG 6222/ AERO ENG 6222	Theory of Elasticity
MECH ENG 6230	Theory Of Plates

## Control Systems

Students pursuing a graduate certificate in control systems will select two courses from Group I and two courses from Group II.

### Group I

Select two of the following:

AERO ENG 5361	Flight Dynamics-Stability And Control
MECH ENG 5481/ AERO ENG 5481	Mechanical And Aerospace Control Systems
MECH ENG 5001/ AERO ENG 5001	Special Topics
MECH ENG 6479/ AERO ENG 6479	Analysis And Synthesis Of Mechanical And Aerospace Systems



**Group II**

Select two of the following:

AERO ENG 5361	Flight Dynamics-Stability And Control
ELEC ENG 5300	Digital Control
ELEC ENG 6300	Linear Control Systems
ELEC ENG 6310	Optimal Control And Estimation

**Energy Conversion and Transport**

A total of four courses from the list below are required for successful completion of the certificate. At least two of these courses must be from core MECH ENG or AERO ENG graduate courses (5000-level) and at least one must be an advanced course (6000-level).

Choose at least two of the following courses:

MECH ENG 4001/ AERO ENG 4001/ NUC ENG 4001/ PHYSICS 3001	Special Topics
MECH ENG 4001/ AERO ENG 4001	Special Topics
MECH ENG 5131/ AERO ENG 5131	Intermediate Thermofluid Mechanics
MECH ENG 5139/ AERO ENG 5139	Computational Fluid Dynamics
MECH ENG 5525/ AERO ENG 5525	Intermediate Heat Transfer
MECH ENG 5527/ AERO ENG 5527	Combustion Processes
MECH ENG 5533	Internal Combustion Engines
AERO ENG 5535	Aerospace Propulsion Systems
MECH ENG 5541	Applied Energy Conversion
MECH ENG 5566	Solar Energy Technology

Choose at least one of the following courses:

MECH ENG 6123/ AERO ENG 6123	Viscous Fluid Flow
MECH ENG 6131/ AERO ENG 6131	Gas Dynamics I
MECH ENG 6135/ AERO ENG 6135	Turbulent Flows - Theory, Measurements and Modeling
MECH ENG 6137/ AERO ENG 6137	Physical Gas Dynamics I
MECH ENG 6527/ AERO ENG 6527	Heat Transfer by Convection

Choose one of the following courses:

MECH ENG 4001/ AERO ENG 4001/ NUC ENG 4001/ PHYSICS 3001	Special Topics
MECH ENG 4001/ AERO ENG 4001	Special Topics
MECH ENG 5527/ AERO ENG 5527	Combustion Processes
MECH ENG 5131/ AERO ENG 5131	Intermediate Thermofluid Mechanics
MECH ENG 5541	Applied Energy Conversion
MECH ENG 5139/ AERO ENG 5139	Computational Fluid Dynamics
MECH ENG 5566	Solar Energy Technology
AERO ENG 5535	Aerospace Propulsion Systems
MECH ENG 5525/ AERO ENG 5525	Intermediate Heat Transfer
MECH ENG 5533	Internal Combustion Engines
MECH ENG 6123/ AERO ENG 6123	Viscous Fluid Flow
MECH ENG 6527/ AERO ENG 6527	Heat Transfer by Convection

MECH ENG 6131/ Gas Dynamics I  
AERO ENG 6131

MECH ENG 6135/ Turbulent Flows - Theory, Measurements and Modeling  
AERO ENG 6135

MECH ENG 6137/ Physical Gas Dynamics I  
AERO ENG 6137

**Engineering Mechanics**

Students enrolled in this graduate certificate program will have a choice from the following list of courses offered to graduate students in mechanical or aerospace engineering:

MECH ENG 5211 Introduction To Continuum Mechanics

MECH ENG 5212/  
AERO ENG 5212 Introduction to Finite Element Analysis

MECH ENG 5220/  
AERO ENG 5220 Advanced Mechanics of Materials

MECH ENG 5234/  
AERO ENG 5234 Stability of Engineering Structures

MECH ENG 5236/  
AERO ENG 5236 Fracture Mechanics

MECH ENG 5238/  
AERO ENG 5238 Fatigue Analysis

MECH ENG 5282/  
AERO ENG 5282 Introduction to Composite Materials & Structures

MECH ENG 6212/  
AERO ENG 6212 Advanced Finite Element Analysis

MECH ENG 6222/  
AERO ENG 6222 Theory of Elasticity

MECH ENG 6230 Theory Of Plates

MECH ENG 6284/  
AERO ENG 6284 Analysis of Laminated Composite Structures

**Manufacturing Automation**

Students pursuing a graduate certificate in manufacturing automation through the mechanical engineering program will complete the following:

Required course:

MECH ENG 5655 Manufacturing Equipment Automation

Select three of the following:

ELEC ENG 5340 Advanced PLC

ELEC ENG 5350 Plantwide Process Control

MECH ENG 5478/  
AERO ENG 5478/  
COMP ENG 5820/  
ELEC ENG 5870 Mechatronics

MECH ENG 5481/  
AERO ENG 5481 Mechanical And Aerospace Control Systems

MECH ENG 5653 Computer Numerical Control of Manufacturing Processes

MECH ENG 5763 Computer Aided Design: Theory and Practice

MECH ENG 6653 Advanced Cnc Of Manufacturing Processes & Engineering Metrology

MECH ENG 6655 Modeling And Control Of Manufacturing Processes

**Victor Birman, Emeritus Professor**

PHD Technion, Haifa, Israel

Director Engineering Education Center in St. Louis. Composite material structures, smart structures and materials, structural dynamics and vibration, buckling and dynamic stability.

**Douglas A Bristow**, Professor

PHD University of Illinois Urbana-Champaign  
Dynamid modeling and control of micro- and nono-positioning systems, atomic force microscopes and additive manufacturing systems; volumetric error compensation; iterative learning control, multi-dimensional control, and signal processing.

**K Chandrashekhara**, Curators Distinguished Professor

PHD Virginia Polytechnic Institute  
Composite materials, smart structures, structural dynamics, finite element analysis, composite manufacturing and experimental characterization.

**Alfred Linden Crosbie**, Curators Distinguished Professor Emeritus

PHD Purdue University  
Multidimensional radiative heat transfer, laser processing of materials, radiative heat transfer in combustion processes, microscale heat transfer, biomedical optics, interaction of radiation with conduction and convection, multiple scattering and polarization of laser beams, solutions of integral equations, and numerical heat transfer.

**L R Dharani**, Curators Distinguished Professor

PHD Clemson University  
Senior Investigator in Graduate Center for Materials Research. Micromechanics of bi-material interfaces, composite materials, fracture mechanics, fatigue and failure analysis of welded structures, wear and friction in composites, fracture and failure of laminated glass.

**Xiangyang Dong**, Assistant Professor

PHD Purdue University  
Mechanics/microstructural evolution of advanced manufacturing & materials processing, multiscale modeling of materials by bridging first-principles calculations, molecular dynamics simulations, & finite element methods, materials design & manufacturing processes of composite & ceramics, relationships between the microstructure, properties, and processing of materials.

**James A Drallmeier**, Curators Distinguished Teaching Professor

PHD University of Illinois Urbana-Champaign  
Department Chair. Combustion, laser based diagnostics for sprays and combustion, optical measurement systems, fuel injection, and internal combustion engines.

**Jie Gao**, Associate Professor

PHD Columbia University  
Nanophotonics devices based on silicon photonics, plasmonics and metamaterials; light-matter interactions in photonic nanostructures; optical sensing; quantum dots; quantum optics and quantum information processing; solar energy harvesting; light emitting devices.

**Kelly O Homan**, Associate Professor

PHD University of Illinois Urbana-Champaign  
Fluid dynamics, heat transfer and thermodynamics of energy systems, heat and mass transfer in buoyant flows, second-law and energy analysis, numerical simulation of transport phenomena and experimental methods.

**Umit O Koylu**, Professor

PHD University of Michigan  
Combustion, environmental technology, soot formation, turbulent flames, laser diagnostics, flame radiation, formation and emission of pollutants, synthesis of nanoparticles, micro-energy systems.

**K Krishnamurthy**, Professor

PHD Washington State University  
Vice Provost for Research. Advanced manufacturing systems, intelligent control, micro-electromechanical systems, nanotechnology, robotics.

**Robert G Landers**, Curators Distinguished Professor

PHD University of Michigan  
Manufacturing, systems, and control; modeling, analysis, monitoring, and control of manufacturing processes; metal cutting processes; laser metal deposition; friction stir welding; freeze extrusion fabrication; integrated design and control; control of alternative energy systems; digital control applications.

**Ming C Leu**, Keith & Pat Bailey Distinguished Professor

PHD University of California-Berkeley  
Rapid prototyping, intelligent manufacturing, virtual reality, CAD/CAM, robotics, mechatronics, automatic control.

**Fue-Wen Frank Liou**, Michael and Joyce Bytnar Product Innovation and Creativity Professor

PHD University of Minnesota at Twin Cities  
Michael and Joyce Bytnar Product Innovation and Creativity Professor of Mechanical Engineering; Director of Manufacturing Engineering. Computer-aided design and manufacturing, rapid prototyping, rapid manufacturing, virtual manufacturing, and micro-machining.

**Ashok Midha**, Professor

PHD University of Minnesota at Twin Cities  
Director of the Product Innovation Creativity Center. Mechanical design, rigid-body and compliant mechanism design, high-performance machinery analysis and design, machine vibration and stability.

**J Keith Nisbett**, Associate Professor

PHD University of Texas-Arlington  
Associate Chair for Mechanical Engineering. Kinematics, mechanical design, and synthesis of mechanisms.

**Anthony Chukwujekwu Okafor**, Professor

PHD Michigan Technological University  
Manufacturing including intelligent machining, metal forming, machine tool dynamics, acoustic emission, sensors, multi-sensor fusion and signal processing, CNC, CAD/CAM, virtual manufacturing, machine tool metrology, neural network and expert system applications; smart structures including intelligent health monitoring, damage assessment of composite structures; non-destructive evaluation.

**Heng Pan**, Associate Professor

PHD University of California-Berkeley  
Additive manufacturing, electronics and photonics manufacturing, thermal/laser assisted manufacturing, laser annealing and crystallization, high-throughput and low cost micro/nano-manufacturing, solution processing of nanomaterials, molecular dynamics simulation, transport phenomena in nano-manufacturing process.

**Jonghyun Park**, Associate Professor

PHD University of Michigan-Ann Arbor  
Advanced li-ion battery, beyond li-ion battery, energy storage systems, renewable energy systems, grid energy storage systems, nano-/macro-mechanics of materials, self-assembly of nanoparticles, nanostructures, multiphysics/multiscale experiment and simulations.

**Yun Seong Song**, Assistant Professor

PHD Massachusetts Institute of Technology  
Physical Human-Robot Interaction (pHRI), Physical Human-Human Interaction (pHHI), Human Movement Assistance, Rehabilitation Robotics, Wearable Devices, Energy-Harvesting from Human Movement, Design and Instrumentation of Medical Devices.

**Daniel S Stutts**, Associate Professor

PHD Purdue University  
Dynamics, vibrations, modeling and development of piezo-actuators and transducers-mechatronics, mechanics of bone, design of orthopedic implants, structural dynamics, optimal design, acoustics.

**Hai-Lung Tsai**, Professor Emeritus

PHD University of California-Berkeley  
Solidification processes, heat transfer and fluid mechanics in materials processing and manufacturing (alloy casting, welding, crystal growth, metal matrix composites, injection molding), laser-based manufacturing (laser welding, cladding, micro-machining, rapid prototyping).

**Cheng Wang**, Associate Professor

PHD University of Illinois at Urbana-Champaign  
Fluid dynamics, micro/nanoscale heat and mass transport, interfacial phenomena, micro/nanofluidics, bioMEMS, lab-on-a-chip, micro/nano-fabrication, bubble dynamics, droplet dynamics, acoustics, acoustic streaming, electrohydrodynamics, electrokinetics, and multi-phase flow.

**Xiaodong Yang**, Associate Professor

PHD Columbia University  
Optical materials and devices in nanophotonics and plasmonics; physics and applications of optical metamaterials; nanoscale optomechanics, optical nanoelectromechanical systems (NEMS); integrated optofluidic devices and optical sensors; photon management for solar/thermal energy harvesting; optical device micro-/nano-fabrication.

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**MECH ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MECH ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Aero Eng 5001).

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**MECH ENG 5131 Intermediate Thermofluid Mechanics** (LEC 3.0)

Derivation of Navier-Stokes equations, analytical solutions of viscous flows; flow in pipes, flow networks; intermediate treatment of boundary layer theory; micro-fluidics and MEMS; introduction to numerical methods for solving fluid flows; and, preliminary treatise on turbulence. Prerequisite: Mech Eng 3131 or Aero Eng 3131. (Co-listed with Aero Eng 5131).

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**MECH ENG 5135 Fluid Machinery** (LEC 3.0)

Fundamental investigation of positive displacement and turbomachinery including pumps, fans, compressors, turbines, and oil hydraulic systems. Operating characteristics, selection, and comparison of types are studied. Prerequisite: Mech Eng 3131 or Aero Eng 5135.

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**MECH ENG 5139 Computational Fluid Dynamics** (LEC 3.0)

Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; one course in fluid mechanics. (Co-listed with Aero Eng 5139).

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**MECH ENG 5205 Lubrication** (LEC 3.0)

Development of basic principles of bearing analysis including manufacture and properties of lubricants, hydrodynamics and hydrostatic lubrication, journal and thrust bearings, ball and roller bearings, boundary considerations, and bearing materials. Prerequisite: Mech Eng 3131.

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**MECH ENG 5211 Introduction To Continuum Mechanics** (LEC 3.0)

Introductory cartesian tensor analysis to aid in the development of the theory of a continuum. Kinematics of deformation, stress tensor, equations of motion, equations of mass and energy balance. Examples from specific material theories in solid and fluid mechanics. Prerequisites: Civ Eng 2210, Math 3304.

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**MECH ENG 5212 Introduction to Finite Element Analysis** (LEC 3.0)

Variational formulation of the governing equations. Finite element model, interpolation functions, numerical integration, assembly of elements and solution procedures. Applications to solid mechanics, fluid mechanics and heat transfer problems. Two-dimensional problems. Computer implementation and use of commercial finite element codes. Prerequisites: Math 3304; senior or graduate standing. (Co-listed with Aero Eng 5212).

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**MECH ENG 5214 Applications Of Numerical Methods To Mechanics Problems** (LEC 3.0)

Numerical solutions of statics, vibrations, and stability problems. Direct stiffness formulations are developed and user-oriented computer codes are used to solve practical structures problems. Computer graphics techniques are utilized to prepare data and display results. Prerequisites: Civ Eng 2210; Mech Eng 2360 or Aero Eng 2360.

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**MECH ENG 5220 Advanced Mechanics of Materials** (LEC 3.0)

Comprehensive insight into mechanics of materials. Topics to include: theories of failure, torsion of noncircular sections, shear flow and shear center, unsymmetric bending, bending of curved members, beams on elastic foundation and pressurization of thick walled cylinders. Prerequisites: Civ Eng 2210, Math 3304. (Co-listed with Aero Eng 5220).

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**MECH ENG 5222 Introduction To Solid Mechanics** (LEC 3.0)

Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: Mech Eng 5211. (Co-listed with Aero Eng 5222).

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**MECH ENG 5229 Smart Materials And Sensors** (LAB 1.0 and LEC 2.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5229, Elec Eng 5270 and Civ Eng 5118).

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**MECH ENG 5234 Stability of Engineering Structures** (LEC 3.0)

Solution of stability problems with applications to columns, plates and shell structures. Torsional and lateral buckling of columns. Buckling under high temperatures. Effect of imperfections introduced by a technological process on stability. Design issues related to stability requirements. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Aero Eng 5234).

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**MECH ENG 5236 Fracture Mechanics** (LEC 3.0)

Linear elastic and plastic mathematical models for stresses around cracks; concepts of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5236).

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**MECH ENG 5238 Fatigue Analysis** (LEC 3.0)

The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints, components and structures, design to prevent fatigue. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5238).

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**MECH ENG 5254 Variational Formulations Of Mechanics Problems** (LEC 3.0)

Introduction and study of variational problems in classical dynamics and solid mechanics emphasizing the concepts of virtual work, minimum potential energy, and complementary energy. Variational inequalities. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Eng Mech 354).

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**MECH ENG 5282 Introduction to Composite Materials & Structures** (LEC 3.0)

Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5282).

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**MECH ENG 5283 Industrial Applications Of Composite Materials Technology** (LEC 3.0)

Composite materials-industrial applications. Fibers and matrices. Fabrication and NDI. Lamination theory overview. Composite joints. Postbuckling. Fatigue and environmental effects. Testing and certification of composite structures. A majority of the presentations will be made by engineers in the industry. Prerequisite: Civ Eng 2210. (Co-listed with Eng Mech 303).

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**MECH ENG 5307 Vibrations I** (LEC 3.0)

Equations of motion, free and forced vibration of single degree of freedom systems and multidegree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studied. The vibration of continuous systems is introduced. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Aero Eng 5307).

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**MECH ENG 5309 Engineering Acoustics I** (LEC 3.0)

Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Aero Eng 5309).

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**MECH ENG 5313 Intermediate Dynamics Of Mechanical And Aerospace Systems** (LEC 3.0)

Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: Mech Eng 3313 or Aero Eng 3613. (Co-listed with Aero Eng 5313).

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**MECH ENG 5420 Signal Processing for Instrumentation and Control** (LEC 3.0)

The course presents fundamental techniques for analysis and processing of experimental data and real-time signals. Continuous- and discrete-time development of signal spectra, Fourier Transform, convolution, filter design, and system identification. The emphasis is on practical problems that arise in instrumentation and control applications. Prerequisites: Math 3304; Mech Eng 3411 or permission of instructor for non-Mech Eng majors.

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**MECH ENG 5449 Robotic Manipulators and Mechanisms** (LAB 1.0 and LEC 2.0)

Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Mech Eng 3313; Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972 or Comp Sci 1570. (Co-listed with Aero Eng 5449).

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**MECH ENG 5478 Mechatronics** (LEC 2.0 and LAB 1.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Aero Eng 5478, Elec Eng 5870 and Comp Eng 5820).

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**MECH ENG 5481 Mechanical And Aerospace Control Systems** (LEC 3.0)

Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mech Eng 4479 or Aero Eng 3361. (Co-listed with Aero Eng 5481).

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**MECH ENG 5519 Advanced Thermodynamics** (LEC 3.0)

After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Mech Eng 2519. (Co-listed with Aero Eng 5519).

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**MECH ENG 5523 Transport Phenomena In Manufacturing Processes** (LEC 3.0)

A study of the important role that transport phenomena (heat and mass transfer and fluid flow) play during various manufacturing processes including metal casting, joining and welding extrusion, forging, crystal growth, chemical deposition, and thermal spray deposition. Prerequisites: Mech Eng 3525 and 3131.

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**MECH ENG 5525 Intermediate Heat Transfer** (LEC 3.0)

Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mech Eng 3525. (Co-listed with Aero Eng 5525).

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**MECH ENG 5527 Combustion Processes** (LEC 3.0)

Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mech Eng 3521. (Co-listed with Aero Eng 5527).

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**MECH ENG 5533 Internal Combustion Engines** (LEC 3.0)

A course dealing primarily with spark ignition and compression ignition engines. Topics include: thermodynamics, air and fuel metering, emissions and their control, performance, fuels, and matching engine and load. Significant lecture material drawn from current publications. Prerequisite: Mech Eng 3521.

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**MECH ENG 5537 Fuel Cell Principles** (LEC 3.0)

Fuel cell fundamentals including thermodynamics, reaction kinetics, mass transport, characterization, and modeling are discussed. Different types of fuel cells such as proton exchange membrane and solid oxide are covered together with subsystem design and system integration as well as environmental impacts. Prerequisites: MECH ENG 3521.

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**MECH ENG 5541 Applied Energy Conversion** (LEC 3.0)

The study of the principles of energy conversion. Specific applications include fuel cells and other direct energy conversion devices used in plug-in hybrid electric vehicles. Prerequisite: Mech Eng 3521.

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**MECH ENG 5543 Energy Efficiency of Vehicles** (LEC 3.0)

Course topics include the energy consumption, energy efficiency, pollution and carbon emissions of vehicles. Energy efficiency models are developed to illustrate how to optimize the energy efficiency of vehicles. Detailed models are developed for gasoline, diesel, electric and hybrid-electric cars and trucks. Prerequisites: Math 2222, Physics 2135.

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**MECH ENG 5544 Non-Intrusive Measurement Methods** (LEC 3.0)

Fundamentals of non-contact measurement methods for engineers. Basic engineering optics with a focus on radiation measurement methods including the effects of various sources and detectors. Prerequisites: Phys 2135; Mech 3525 or consent of instructor for non-Mech Eng majors.

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**MECH ENG 5566 Solar Energy Technology** (LEC 3.0)

Introduction to the nature of solar radiation and associated thermal energy transfers. Methods of collecting and storing solar energy. Analysis and design of systems for utilizing solar energy, including heating and cooling. Prerequisite: Mech Eng 3525, or consent of instructor for non-Mech Eng majors.

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**MECH ENG 5567 Heat Pump And Refrigeration Systems** (LEC 3.0)

The various methods used in the thermal design and analysis of both refrigeration and heat pumps systems are investigated. Various methods of producing heating and cooling are examined including vapor compression, absorption, air cycle, steam jet, and thermoelectric systems. Prerequisites: Mech Eng 3521, 3525.

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**MECH ENG 5570 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Nuc Eng 4370, Physics 4543).

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**MECH ENG 5571 Environmental Controls** (LEC 3.0)

Theory and applications of principles of heating, ventilating, and air conditioning equipment and systems; design problems. Physiological and psychological factors relating to environmental control. Prerequisites: Mech Eng 3521 and accompanied or preceded by Mech Eng 3525; or Mech Eng 2527 and Civ Eng 3330.

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**MECH ENG 5575 Mechanical Systems For Environmental Control** (LEC 3.0)

Analysis of refrigeration, heating, and air-distribution systems. Synthesis of environmental control systems. Prerequisites: Mech Eng 3521 and 3525; or Mech Eng 2527 and Civ Eng 3330.

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**MECH ENG 5606 Material Processing By High-Pressure Water Jet** (LEC 3.0)

Methods of generating high pressure water jets; standard equipment, existing techniques, and basic calculations. Application of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. Prerequisite: Mech Eng 3131 or undergraduate fluids course. (Co-listed with Min Eng 5413).

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**MECH ENG 5644 Interdisciplinary Problems In Manufacturing Automation** (LEC 2.0 and LAB 1.0)

The course will cover material necessary to design a product and the fixtures required to manufacture the product. Participants will gain experience with CAD/CAM software while carrying out an actual manufacturing design project. (Co-listed with Chem Eng 4310, Eng Mgt 5315).

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**MECH ENG 5653 Computer Numerical Control of Manufacturing Processes** (LEC 2.0 and LAB 1.0)

Fundamental theory and application of computer numerical controlled machine tools from the viewpoint of design principles, machine structural elements, control systems, and programming. Projects include manual and computer assisted part programming and machining. Prerequisites: Preceded or accompanied by Mech Eng 3653.

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**MECH ENG 5655 Manufacturing Equipment Automation** (LAB 1.0 and LEC 2.0)

Manufacturing automation at the equipment level. Topics include sensors, actuators, and computer interfacing for manufacturing equipment, dynamic modeling and control of manufacturing equipment, interpolation, coordinated motion control, kinematic and geometric error modeling, and runout. Prerequisites: Preceded or accompanied by Mech Eng 4479 or equivalent.

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**MECH ENG 5656 Design For Manufacture** (LEC 3.0)

Course covers the approach of concurrent product and process design. Topics includes: principle of DFM, New product design process, process capabilities and limitations, Taguchi method, tolerancing and system design, design for assembly and AI techniques for DFM. Prerequisites: Mech Eng 3708, Mech Eng 3653.

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**MECH ENG 5702 Synthesis Of Mechanisms** (LEC 3.0)

Synthesis of planar mechanisms for function generation, path generation, and motion generation. Emphasis is on analytical methods for synthesis. Prerequisite: Mech Eng 3313.

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**MECH ENG 5704 Compliant Mechanism Design** (LEC 3.0)

Introduction to compliant mechanisms; review of rigid-body mechanism analysis and synthesis methods; synthesis of planar mechanisms with force/energy constraints using graphical and analytical methods; pseudo-rigid-body models; force-deflection relationships; compliant mechanism synthesis methods; and special topics, e.g. bistable mechanisms, constant-force mechanisms, parallel mechanisms, and chain algorithm in design. Emphasis will be on applying the assimilated knowledge through a project on compliant mechanisms design. Prerequisites: Mech Eng 3313, Civ Eng 2210.

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**MECH ENG 5708 Rapid Product Design And Optimization** (LEC 3.0)

Product Life cycle design; Finding design solutions using optimization technique; Rapid product realization using rapid prototyping and virtual prototyping techniques. Prerequisite: Mech Eng 3708.

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**MECH ENG 5709 Machine Design II** (LEC 3.0)

A continuation of the study of machine elements; bearings, spur, bevel, worm, and helical gearing, and indeterminate machine elements; impact and shrink stresses. Prerequisite: Mech Eng 3708.

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**MECH ENG 5715 Concurrent Engineering** (LEC 3.0)

Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mech Eng 3313 or Aero Eng 3131, and Civ Eng 2210. (Co-listed with Aero Eng 5715).

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**MECH ENG 5757 Integrated Product And Process Design** (LEC 3.0)

Emphasize design policies of concurrent engineering and teamwork, and documenting of design process knowledge. Integration of product realization activities covering important aspects of a product life cycle such as "customer" needs analysis, concept generation, concept selection, product modeling, process development, and end of product life options. Prerequisites: Junior or above standing. (Co-listed with ENG MGT 5515).

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**MECH ENG 5758 Integrated Product Development** (LEC 1.0 and LAB 2.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, process quality, cost, supply chain management, and product support. Students will produce a final engineering product at the end of the project. Prerequisite: Eng Mgt 5515 or Mech Eng 5757 or Mech Eng 3653 or Mech Eng 5708. (Co-listed with Eng Mgt 5516).

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**MECH ENG 5760 Probabilistic Engineering Design** (LEC 3.0)

The course deals with uncertainties in engineering analysis and design at three levels - uncertainty modeling, uncertainty analysis, and design under uncertainty. It covers physics-based reliability analysis and reliability-based design, robustness assessment and robust design, their integration with design simulations, and their engineering applications. Prerequisite: Mech Eng 3708 or Aero Eng 3361. (Co-listed with Aero Eng 5760).

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**MECH ENG 5761 Engineering Design Methodology** (LEC 3.0)

This course examines structured engineering design theory and methodologies for conceptual design and redesign of products. Topical coverage includes customer needs gathering, functional modeling, engineering specifications creation (OFD), concept generation, selection and design embodiment. Team work/hands-on projects emphasized. Prerequisite: At least Senior standing in engineering.

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**MECH ENG 5763 Computer Aided Design: Theory and Practice** (LEC 2.0 and LAB 1.0)

Lectures cover the fundamentals of computer-aided design with emphasis on geometric modeling of curves, surfaces and solids, CAD/CAM data exchange, and computer graphics. In the lab session, students practice with commercial CAD/CAM systems including NX and SolidWorks to gain practical experience. Prerequisites: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; Mech Eng 2761; Math 2222; at least Junior standing.

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**MECH ENG 5764 Introduction to Decision Analysis** (LEC 3.0)

This course is an introduction to decision analysis, a decision-making method under uncertainty. The course topics include probability theory, influence diagram, decision tree, subjective probability, sensitivity analysis, value of information, risk attitude, and utility models. Prerequisite: Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117.

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**MECH ENG 5830 Applied Computational Methods** (LEC 3.0)

Detailed study of computational methods for efficient solution of selected fluids, structures, thermodynamics, and controls problems in aerospace and mechanical engineering. Besides basic numerical techniques, topics covered include gradient-based optimization and uncertainty quantification. Prerequisite: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; Math 3304. (Co-listed with Aero Eng 5830).

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**MECH ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

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**MECH ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MECH ENG 6010 Seminar** (LEC 0.0-1.0)

Discussion of current topics. (Co-listed with Aero Eng 6010).

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**MECH ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MECH ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MECH ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**MECH ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MECH ENG 6123 Viscous Fluid Flow** (LEC 3.0)

Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; boundary layer theory for incompressible and compressible flows; stability and transition. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Aero Eng 6123).

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**MECH ENG 6131 Gas Dynamics I** (LEC 3.0)

A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandtl-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Aero Eng 6131).

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**MECH ENG 6135 Turbulent Flows - Theory, Measurements and Modeling** (LEC 3.0)

Navier-Stokes equations; statistical description and mean-flow equations; behavior of free shear and wall bounded flows; the energy cascade; turbulence spectra and Kolmogorov hypothesis; measurement techniques: PIV, hot-wires, LDV; turbulence modeling for transport processes and closure schemes for RANS equations; evaluation of model constants, introduction to LES, DNS and hybrid-RANS. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Aero Eng 6135).

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**MECH ENG 6137 Physical Gas Dynamics I** (LEC 3.0)

Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and non-equilibrium gas properties and gas flows are included. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Aero Eng 6137).

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**MECH ENG 6212 Advanced Finite Element Analysis** (LEC 3.0)

Higher order, isoparametric and mixed finite elements. Eigenvalue and time-dependent problems. Solution procedures for dynamic analysis. Implicit and explicit methods. Applications to viscous incompressible fluid and plate bending problems. Three-dimensional problems. Nonlinear finite element analysis. Practical applications using commercial software. Prerequisite: Mech Eng 5212 or Aero Eng 5212. (Co-listed with Aero Eng 6212).

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**MECH ENG 6222 Theory of Elasticity** (LEC 3.0)

Formulation and study of boundary-value problems in 2-D linear elastostatics: Equilibrium and compatibility. Stress function formulations in Cartesian and polar coordinates. Curved beam, wedge and plane contact problems. Dislocations and cracks. Thermoelasticity. Prerequisites: CIV ENG 2210. (Co-listed with Aero Eng 6222).

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**MECH ENG 6230 Theory Of Plates** (LEC 3.0)

General coverage of various approaches to plate problems and the application of these methods to practical problems. Special topics include applications to elastic foundations, buckling and energy methods in plate theory. Prerequisite: Math 5325.

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**MECH ENG 6232 Theory Of Shells** (LEC 3.0)

General theory of stress analysis of shells based on topics in differential geometry and general elasticity theory. Theory is applicable to studies of the elastic behavior of flat plates and shells, buckling and post-buckling behavior of shells, and provides a basis for all shell theories which account for anisotropy, plasticity, creep, thermal strains, internal reinforcements, and transverse shearing deformations. Prerequisite: Math 5325.

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**MECH ENG 6236 Advanced Fracture Mechanics** (LEC 3.0)

Mathematical theories of equilibrium cracks and brittle fracture, mathematical analysis of elastic-plastic fracture mechanics, COD, R-curve and J-integral analysis. Prerequisite: Aero Eng 5236 or Mech Eng 5236.

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**MECH ENG 6284 Analysis of Laminated Composite Structures** (LEC 3.0)

An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Aero Eng 6284).

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**MECH ENG 6285 Mechanics Of Composite Materials** (LEC 3.0)

Effective moduli of spherical, cylindrical, and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear lag and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Aero Eng 6285).

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**MECH ENG 6307 Advanced Vibrations** (LEC 3.0)

Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems, and random excitations. Prerequisite: Mech Eng or Aero Eng 5307. (Co-listed with Aero Eng 6307).

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**MECH ENG 6309 Engineering Acoustics II** (LEC 3.0)

Expanded treatment of the theory of sound generation and propagation. The acoustic source, dipole, and quadrupole. Noise sources due to vibration and fluid flow. Sound propagation in the atmosphere. The transmission of sound in ducts. Propeller, fan, and jet noise. Prerequisite: Mech Eng or Aero Eng 5309. (Co-listed with Aero Eng 409).

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**MECH ENG 6313 Advanced Dynamics Of Machinery** (LEC 3.0)

Current problems in aerospace dynamics are treated using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations; stability of systems, to include approximate techniques. Prerequisite: Mech Eng or Aero Eng 5313. (Co-listed with Aero Eng 6313).

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**MECH ENG 6447 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Eng Mgt 6410, Sys Eng 6217 and Comp Sci 6202).

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**MECH ENG 6458 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Aero Eng 6458 and Sys Eng 6215).

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**MECH ENG 6479 Analysis And Synthesis Of Mechanical And Aerospace Systems** (LEC 3.0)

A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mech Eng 5481 or Aero Eng 5481. (Co-listed with Aero Eng 6479).

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**MECH ENG 6481 Advanced Topics in Decision and Control** (LEC 3.0)

This course will deal with latest topics in the areas of decision and control. Course may be repeated if topics vary. Prerequisite: Aero Eng 5481 or Mech Eng 5481 or equivalent. (Co-listed with Aero Eng 6481).

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**MECH ENG 6525 Heat Transfer by Conduction** (LEC 3.0)

A study of conduction heat transfer in solids by analytical and other methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6525).

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**MECH ENG 6526 Micro-/Nano-Scale Thermophysics and Energy Transport** (LEC 3.0)

Introduces advanced statistical thermodynamics, nonequilibrium thermodynamics, kinetic theory, and quantum theory to analyze thermophysics and energy transport for microscale and nanoscale systems. Covers the fundamental concepts of photons, electrons, and phonons in the forms of waves and particles. Includes applications to ultrafast laser processing. Prerequisite: Mech Eng 5525.

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**MECH ENG 6527 Heat Transfer by Convection** (LEC 3.0)

An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current topics in convection. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6527).

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**MECH ENG 6529 Heat Transfer by Radiation** (LEC 3.0)

A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6529).

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**MECH ENG 6541 Advanced Energy Conversion** (LEC 3.0)

An analytical study of power producing systems with emphasis on new techniques and energy sources. All basic methods of energy conversion are covered from detailed physical descriptions to mathematical analysis. Included are advanced heat engines, nuclear power reactors, thermoelectric engines, magnetohydrodynamic devices, solar energy, fuel cells, and recent developments. Prerequisite: Mech Eng (or Aero Eng) 5519, or Mech Eng (or Aero Eng) 5525.

**MECH ENG 6575 Advanced Environmental Control** (LEC 3.0)

The study of environmental control systems including their sizing, control, and energy requirements. Use of major energy analysis programs for system evaluation. Prerequisite: Mech Eng 5575.

**MECH ENG 6585 Advanced Optical Materials and Structures** (LEC 3.0)

Fundamental principles and advanced topics in optical materials and structures covering areas of photonics, plasmonics and metamaterials, and nanofabrication techniques. Prerequisite: Elec Eng 5200 or equivalent.

**MECH ENG 6653 Advanced Cnc Of Manufacturing Processes & Engineering Metrology** (LEC 2.0 and LAB 1.0)

Advanced treatment of Computer Numerical Control (CNC) part programming and machine tool metrology. Topics include mathematical modeling and characterization of machine tools and Coordinate Measuring Machines (CMMs); Measurement and analysis of dimensional accuracy, surface finish, precision, and uncertainty; Machine tool error modeling and compensation; Virtual Numerical Control (VNC) Machine Tool modeling, programming, simulation and process verification/ optimization. Projects include advanced CNC programming and simulation. Prerequisite: Mech Eng 5653.

**MECH ENG 6655 Modeling And Control Of Manufacturing Processes** (LEC 3.0)

This course covers control-oriented modeling, simulation, and control of manufacturing processes. Topics include digital control, control system hardware, servomechanisms, interpolation, coordinated motion control, regenerative chatter, and control of machining and non-traditional processes. Control algorithms are implemented on a machining center. Prerequisites: Mech Eng 5655, Mech Eng 5481.

**MECH ENG 6657 Laser Aided Manufacturing And Materials Processing** (LEC 3.0)

Fundamental studies in laser aided manufacturing and materials processing including laser principles and optics, physics of laser-materials interaction, interface responses for rapid solidification, theories on non-equilibrium synthesis, modeling of transport phenomena, optical sensing techniques, current topics and considerations for lasers in manufacturing. Prerequisite: Mech Eng 5525.

**MECH ENG 6659 Advanced Topics in Design and Manufacturing** (LEC 3.0)

Various topics in the area of design and manufacturing will be covered in this course: development of flexible manufacturing systems, CAD/CAM integration, rapid prototyping, etc. Prerequisites: Mech Eng 5655 or Mech Eng 5708 or equivalent.

**MECH ENG 6663 Advanced Digital Design and Manufacturing** (LEC 3.0)

This course covers freeform modeling, reverse engineering, numerical control path generation for material removal and addition, and virtual reality based digital design and manufacturing. Students learn theoretical and fundamental aspects of these topics from lectures and project exercises. Prerequisites: Mech Eng 5708 or Mech Eng 5757 or Mech Eng 5763 or equivalent.

**MECH ENG 6704 Mechanics of Machinery** (LEC 3.0)

Rigid-body kinematics, dynamics, and synthesis of mechanisms; cam-follower mechanisms; mathematical modeling of mechanisms containing elastic elements; transient and steady-state vibration response; parametric instability in elastic mechanisms; advanced topics in compliant mechanisms; high performance mechanisms will be emphasized. Prerequisites: Vector & matrix analysis; introductory planar kinematic & dynamic analysis of mechanisms; MECH ENG 5704 or equivalent.

**MECH ENG 6761 Modern Product Design** (LEC 3.0)

Modern product development, design and prototyping are examined from a product architecture standpoint in this course. Functional modeling techniques are used to establish the architecture of a product and recently developed theories and techniques for design are covered. A prototyping project is required to provide immediate application of the theories. Prerequisite: Aero Eng 5758 /Eng Mgt 4312 or Mech Eng 5708 or Mech Eng 5656.

## Metallurgical Engineering

The metallurgical engineering program in the department of materials science and engineering offers comprehensive graduate education in a number of areas including physical and mechanical metallurgy, extractive metallurgy, metals casting, joining and forming, and advanced additive manufacturing. Further information on these opportunities and facilities available to carry out research in metallurgical engineering may be found under materials science and engineering.

## Degree Requirements

M.S. and Ph.D. degrees are offered in metallurgical engineering. Recognizing the educational value of research, most metallurgical engineering M.S. degree candidates complete a thesis program. Non-thesis exceptions may be granted in special circumstances.

The total number of hours required for the M.S. in metallurgical engineering is 30. A minimum of 6 hours of 6000-level lectures and a minimum of 11 hours graduate research on the Missouri S&T campus are required. A maximum of 6 hours of 4000-level lectures may be accepted.

The minimum number of hours (beyond the bachelor's degree) required for the Ph.D. in metallurgical engineering is 72. At least 12 hours of course work outside metallurgy is recommended, a minimum of 24 hours will be dissertation research, and a minimum of 24 hours must be course work. Students will also be required to take and pass qualifying and comprehensive exams in accordance with Missouri S&T rules.

## Degree Requirements

M.S. and Ph.D. degrees are offered in metallurgical engineering.

The minimum number of hours (beyond the bachelor's degree) required for the Ph.D. in metallurgical engineering is 72. At least 12 hours of

course work outside metallurgy is recommended, a minimum of 24 hours will be dissertation research, and a minimum of 24 hours must be course work. Students will also be required to take and pass qualifying and comprehensive exams in accordance with Missouri S&T rules.

## Iron and Steel Metallurgy

Missouri University of Science and Technology offers a graduate certificate in Iron and Steel Metallurgy for working professionals. The graduate certificate program consists of four courses from existing graduate-level courses. While the students admitted to the certificate program will have non-matriculated status, if they complete the four course sequence with a grade of B or better in each of the courses taken, they will be admitted to the master's degree program, if they so choose. The certificate credits taken by students admitted to the master's program will count toward their master's degrees.

The Iron and Steel Metallurgy Certificate Program is open to all persons holding a bachelor's, master's, or doctorate degree in engineering, science, and/or mathematics and who have a minimum of one year of professional employment experience, or are currently accepted into a graduate degree program at Missouri S&T. Once admitted to the program, the student must take the four designated courses. In order to receive a graduate certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses. Once admitted to the program, a student will be given three years to complete the program.

A student admitted to the Iron and Steel Metallurgy Certificate Program will have non-degree graduate status; however, they will earn graduate credit for the courses they complete. If the four-course sequence is completed with a grade of B or better in each of the courses taken, the student, upon application, will be admitted to the master's degree program sponsoring the graduate certificate, provided that all other program prerequisites and admission requirements are met. The certificate credits taken by the student admitted to the master's degree program will count toward their master's degree. Students who do not have all of the prerequisite courses necessary to begin the courses in the Iron and Steel Metallurgy Certificate Program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Students enrolled in this certificate will take one required course and three elective courses.

Choose one required course from the following:

MET ENG 5450	Advanced Steelmaking	3
MET ENG 6320	Advanced Steels and Their Treatment	3

Choose three courses from the following:

MET ENG 5310	Corrosion and Its Prevention	3
MET ENG 5440	Metal Deformation Processes	3
MET ENG 5450	Advanced Steelmaking	3
MET ENG 5470	Ferrous Metals Casting	3
MET ENG 6320	Advanced Steels and Their Treatment	3
MS&E 6130	Kinetic Theory for Materials	3

**Note:** MET ENG 5450 and MET ENG 6320 can be taken as the required course or as an elective, but not both.

**Laura Bartlett**, Associate Professor  
PHD Missouri University of Science and Technology

**Arezoo Emdadi**, Assistant Professor  
PHD Missouri University of Science and Technology

**Yijia Gu**, Assistant Professor  
PHD Pennsylvania State University

**Simon Lekakh**, Research Professor  
PHD Belorussian Polytechnic Institute

**F Scott Miller**, Teaching Professor  
PHD University of Missouri-Rolla  
Associate Chair for Undergraduate Programs

**Michael Scott Moats**, Professor  
PHD University of Arizona  
Associate Chair for Graduate Programs

**Joseph W Newkirk**, Professor  
PHD University of Virginia

**Ronald J O'Malley**, Professor  
PHD Massachusetts Institute of Technology  
F. Kenneth Iverson Chair Professor in Steelmaking Technologies, Director of the Kent D. Peaslee Steel Manufacturing Research Center.

**David C Van Aken**, Professor Emeritus<sup>1</sup>  
PHD University of Illinois Urbana

**Haiming Wen**, Assistant Professor  
PHD University of California-Davis

**MET ENG 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MET ENG 5001 Graduate Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**MET ENG 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**MET ENG 5099 Research** (IND 0.0-15)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**MET ENG 5110 High Temperature And Corrosion Resistant Alloys** (LEC 3.0)  
Fabrication and use of nickel, titanium, and refractory metal based alloys for use at high temperatures or in chemically corrosive environments. Properties and strengthening mechanisms of these alloys. Theory of high temperature oxidation and corrosion and design of alloys to prevent them. Prerequisites: Met Eng 3130, 2125.

**MET ENG 5150 Introduction to Metal Additive Manufacturing** (LEC 3.0)

Metal and alloys associated with Additive Manufacturing (AM). Issues with powders and wires as starting materials, safety, solidification mechanisms and development of microstructure and defects, AM part performance, and mechanical properties. Current alloys being utilized and future materials being developed. Prerequisite: Met Eng 2110.

**MET ENG 5160 Mechanical Metallurgy** (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication. Prerequisites: Met Eng 3120, 3125, Civ Eng 2210.

**MET ENG 5170 Nuclear Materials I** (LEC 3.0)

Fundamentals of materials selection for components in nuclear applications. Design and fabrication of UO<sub>2</sub> fuel; reactor fuel element performance; mechanical properties of UO<sub>2</sub>; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110. (Co-listed with Nuc Eng 4241).

**MET ENG 5171 Nuclear Materials II** (LEC 3.0)

Extractive metallurgy of uranium, thorium, and zirconium. Equation of state of UO<sub>2</sub> and fuel chemistry. LMFBR fuel and interaction of sodium and stainless steel. Materials for fusion and other advanced nuclear applications. Reprocessing of spent fuel and disposal. Prerequisite: Met Eng 5170.

**MET ENG 5220 Recent Advances In Extractive Metallurgy** (LEC 2.0)

A survey of extractive processes recently developed in the light of modern requirements with respect to raw materials, product quality, environmental impact, energy consumption, capital cost and process control. Prerequisite: Met Eng 4350.

**MET ENG 5270 Mineral Processing II (Mechanics and Design)** (LAB 1.0 and LEC 2.0)

Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisite: Min Eng 3412. (Co-listed with Min Eng 5424).

**MET ENG 5310 Corrosion and Its Prevention** (LEC 3.0)

A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 3120 or Cer Eng 3230. (Co-listed with Chem Eng 5315).

**MET ENG 5330 Nonferrous Alloys** (LEC 3.0)

Structure and properties of nonferrous alloys (Al, Ti, Mg, Ni and Cu) are described. The role of processing and microstructure in the development of mechanical properties is emphasized. Prerequisite: Met Eng 3130 or Met Eng 5810.

**MET ENG 5420 Advanced Metals Casting** (LEC 3.0)

An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Design of castings and metals casting mold features using commercial casting process simulation software. Prerequisite: Met Eng 3420 or Mech Eng 2653.

**MET ENG 5425 Metals Casting Laboratory** (LAB 1.0)

An advanced laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, highquality castings. Prerequisite: Accompanied or preceded by Met Eng 4420.

**MET ENG 5430 Metals Joining** (LEC 2.0)

Metals joining processes such as welding and brazing. Effects of welding on materials. Treatment and properties of welded joints. Welding defects and quality control. Prerequisite: Met Eng 2110 or 3420.

**MET ENG 5440 Metal Deformation Processes** (LEC 3.0)

An introduction to metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisite: Met Eng 3120 and Met Eng 3420 both with "C" or better grade.

**MET ENG 5450 Advanced Steelmaking** (LEC 3.0)

This course is designed to provide students with an enhanced understanding of the chemistry and physics of ironmaking, steelmaking and casting, to apply these concepts to a wide range of problems in modern steelmaking and casting operations, and to perform advanced design and operational calculations associated with refining and continuous casting processes. Prerequisite: Grade of "C" or better in Cer Eng 3230 or Met Eng 3330.

**MET ENG 5460 Metal Coating Processes** (LEC 3.0)

Introduction to the current technologies used to enhance metal performance, particularly corrosion resistance, by overlay coatings. Deposition processes are emphasized and the fundamentals of the behavior of the films in high technology and electronic materials applications is discussed. Prerequisite: Senior or Graduate Standing.

**MET ENG 5470 Ferrous Metals Casting** (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment. Prerequisite: Met Eng 4420 or Met Eng 5420 or graduate standing with permission of instructor.

**MET ENG 5480 Refining Of Metals** (IND 2.0-3.0)

Principles and applications of refined metal production by electrochemical methods. The course will address basic copper and zinc processing, electrometallurgy, anodes and anodic processes, cathode deposit control and contamination mechanisms, Faraday's Law and current efficiency, and current state of practice. Prerequisite: Cer Eng 3230 and Met Eng 3220 or graduate standing.

**MET ENG 5510 Nondestructive Testing** (LEC 3.0)

Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Elec Eng 5670).

**MET ENG 5515 Nondestructive Testing Laboratory** (LAB 1.0)

Application of radiological and ultrasonic methods of nondestructive testing of metallic materials. A radiographic X-ray units and ultrasonic equipment are used in the inspection of a variety of materials and manufactured parts. Prerequisite: Accompanied or preceded by Met Eng 5510.

**MET ENG 5520 Electron Microscopy** (LEC 3.0)

A course in the theory and application of both scanning and transmission electron microscopy and x-ray microanalysis. Topics considered are electron optics, image formation and analysis; x-ray generation, detection and analysis; and characterization of fracture surfaces. Prerequisites: Met Eng 3130 and Met Eng 2125, or a course in optical microscopy.

**MET ENG 5525 Scanning Electron Microscopy Lab** (LAB 1.0)

A course in the practical use and operation of scanning electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

**MET ENG 5620 Materials Behavior** (LEC 3.0)

A course in crystal defects and deformation; mechanical testing; creep; fracture mechanics and fatigue. Prerequisites: Grade of "C" or better in both Met Eng 2110 and Met Eng 3120.

**MET ENG 5630 Environmental Aspects Of Metals Manufacturing** (LEC 3.0)

Introduction to environmental aspects of metal extraction, melting, casting, forming, and finishing. Subjects include history of environmental movement and regulations permitting, risk analysis, disposal and recycling of metal manufacturing residues, environmental ethics, environmental technologies and case studies. Prerequisite: Junior/Senior standing.

**MET ENG 5810 Principles Of Engineering Materials** (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Cer Eng 5810).

**MET ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MET ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**MET ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**MET ENG 6160 Advanced Mechanical Metallurgy** (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication.

**MET ENG 6320 Advanced Steels and Their Treatment** (LEC 3.0)

Industrially important ferrous alloys are described and classified. The selection of proper heat treatments to facilitate fabrication and to yield required service properties in steels suitable for various applications is considered. Prerequisites: Met Eng 3130 and Met Eng 2125.

**MET ENG 6325 Advanced Ferrous Microstructures** (LAB 1.0 and LEC 1.0)

Course provides an in-depth explanation of microstructural development during solidification, thermo-mechanical processing, and heat treatment of steel. Topics: microscopy, metallography, the Fe-C phase diagram, solidification, homogenization, grain size control, formation of microstructures upon heating/cooling. Term paper and presentation required.

**MET ENG 6440 Advanced Metal Deformation Processes** (LEC 3.0)

Advanced metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisites: A grade of "C" or better in both Met Eng 3120 and Met Eng 3420.

**MET ENG 6470 Advanced Ferrous Metals Casting** (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment.

**MET ENG 6535 Transmission Electron Microscopy Lab** (LAB 1.0)

A course in the practical use and operation of transmission electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

## Mining Engineering

The mining engineering program in the department of mining and nuclear engineering offers the graduate certificate, master of engineering (M.E.), master of science (M.S.), doctor of philosophy (Ph.D.) and doctor of engineering (D.E.) degrees in mining engineering. The M.S. with thesis and Ph.D. degrees require research components for program completion. The core research strengths include surface mining methods and heavy mining machinery, mine ventilation and mine atmospheric control, explosives engineering, sustainable development and mine optimization, rock mechanics and ground control, minerals, coal and materials processing, minerals and energy economics, and underground mining methods and equipment. Graduate students in any of these programs must consult the graduate degree requirements in mining engineering, the graduate catalog of Missouri S&T and their respective advisors.

The graduate certificate program requires 12 credit hours in core courses. Students must have a minimum cumulative GPA of 3.00/4.00 to receive the graduate certificate in mining engineering. The ME program requires a minimum of 30 credit hours, offered via distance (online). The required credit hours include 15 core credit hours, 12 credit hours in technical electives and 3 credit hours for a semester project. The mining engineering program offers an M.S. degree with thesis for onsite students and an M.S. by coursework option for distance students. The M.S. degree with thesis option requires a minimum of 30 credit hours, including the required research for the thesis. The program requirements must include a minimum of 6 credit hours of 6000-level lecture courses, 6 credit hours of courses outside the major field, and 6 credit hours for thesis research. M.S. candidates must pass a final oral examination of the thesis to complete the program. The M.S. degree by coursework option requires a minimum of 30 credit hours, including a minimum of 9 credit hours of 6000-level lecture courses and 3 credit hours for a semester project. The Ph.D. program requires a minimum of 3 years of full-time study beyond the bachelor's degree, including research work for the dissertation. Ph.D. candidates must complete at least 15 credit hours of course work at Missouri S&T and are required to pass the qualifying, comprehensive and final oral examinations of the Ph.D. program. The D.E. degree requires a minimum of 3 years of full-time study beyond the bachelor's degree, including research work for the dissertation. D.E. students must pass the qualifying, comprehensive and final oral examinations and must also satisfy an engineering internship requirement.

## Major Research Areas

The eight research major areas include (i) surface mining methods and heavy mining machinery; (ii) mine ventilation and mine atmospheric control; (iii) explosives engineering; (iv) sustainable development and mine optimization; (v) rock mechanics and ground control; (vi) mineral, coal and materials processing; (vii) minerals and energy economics; and (viii) underground mining methods and equipment. **Surface mining methods and heavy mining machinery research** focuses on surface mining, formation excavation, heavy machinery imaging and integration, mine safety and health, machine and component health, equipment vision, intelligent mining systems and stochastic processes and risks simulation. Specific research frontiers include (i) mining methods, design and production systems; (ii) formation failure dynamics, machine-formation interactions; (iii) kinematics, dynamics and virtual prototype simulation; (iv) machine health and longevity; (v) augmented equipment vision; (vi) machine vibrations and operator health; (vii) tire durability management; (viii) intelligent excavation; (ix) machine automation; (x) random fields and stochastic processes; (xi) numerical, parametric and stochastic simulation.

**Mine ventilation and mine atmospheric control research** focuses on mine ventilation network modeling and planning, diesel particulate matter (DPM), mine dust control, mine fire simulation and firefighting. Specific research frontiers include (i) ventilation network simulation, (ii) DPM discharge dissipation modeling and control strategies, (iii) spontaneous combustion modeling, firefighting and emergency planning; and (iv) computational fluid dynamics modeling of particulate matter. **Explosives engineering research** focuses on improvements in commercial explosives and blasting agents, mining-related uses of explosives, explosives safety, blast-resistant structures, barriers to blast, fragments, and ballistic penetration, and explosive-driven pulsed power. Specific research frontiers include (i) design, evaluation, analysis, and test; (ii) barrier concepts, standoff distance analysis, barrier design and test; (iii) design,

evaluation, analysis, and test of explosive-driven pulsed power generator concepts and power conditioning systems.

**Sustainable development and mine optimization research** focuses on reserve estimation and ore control, production scheduling and optimization, and critical materials sustainability assessment and modeling. Specific research frontiers include (i) geostatistics, ore (dig) outline optimization; (ii) mixed integer LP formulations, computational efficiency, discrete event simulation, optimization, energy efficiency modeling; (iii) mining applications of life cycle assessment, life cycle sustainability assessment, social acceptance modeling, global critical material supply chain sustainability modeling, reclaimed mine land stray-gas hazards. **Rock Mechanics and ground control** research focuses on ground control, acoustic emission/microseismic, geophysical methods in mines, and non-destructive testing. Specific research frontiers include (i) pillar design, mine support, rockburst, slope stability; (ii) monitoring design, location methods, error analysis; (iii) geotomography, in-seam seismic method, void detection; and (iv) integrity of structures and monitoring of aging infrastructure.

**Minerals, coal and materials processing research** focuses on mineral processing, tailings management, polymer science, nanotechnology, interfacial science, colloidal interactions in aqueous systems, clays, coal-based fuels, ultrafine and submicron grinding, slurry rheology, carbon separation and synthetic fuels. **Minerals and energy economics research** focuses on supply and use of minerals and energy in society, minerals and energy markets and electricity markets, minerals and energy and economic growth, economics of minerals and energy infrastructure, minerals and energy policy, minerals and energy derivatives, minerals and energy demand forecast, elasticity of supply and demand in minerals and energy markets, climate change and climate policy, and sustainable minerals and energy development. **Underground mining methods and equipment research** focuses on mass mining, machine design and automation, underground mine support, machine vibration, novel mining methods, numerical modeling, virtual prototype simulation and computational fluid dynamics.

## Major Research Facilities

Mining, minerals and explosives engineering research initiatives are carried out in world-class environments at Missouri S&T. Major research facilities include the following:

- Energetics Research Facility (p. 41)
- Experimental Mine (<http://catalog.mst.edu/graduate/specialfacilitiesandprograms/experimentalmine/#text>)
- Mineral Processing Laboratory (p. 47)
- Rock Mechanics and Explosives Research Center (<http://catalog.mst.edu/graduate/researchcentersandinstitutes/rockmechanicsandexplosivesresearchcentermerc/#text>)
- Rock Mechanics Laboratory (p. 48)
- Virtual Surface Mining Simulator (p. 49)
- High Pressure Waterjet Laboratory (<http://catalog.mst.edu/graduate/specialfacilitiesandprograms/highpressurewaterjetlaboratory/#text>)

**Lana Z Alagha**, Associate Professor  
PHD University of Texas at Dallas  
Mineral processing, tailings management, polymer science, nanotechnology, interfacial science, colloidal interactions in aqueous systems clays.

**Kwame Awuah-Offei**, Associate Professor<sup>1</sup>

PHD University of Missouri-Rolla

Life cycle sustainability assessment, community acceptance modeling, energy efficiency modeling, production optimization, CO2 hazard delineation and innovative post-mining land uses for underground mines.

**Samuel Frimpong**, Professor<sup>1</sup>

PHD University of Alberta, Canada

Surface mining, formation excavation, heavy machinery imaging and integration, intelligent mining systems, stochastic processes and risks simulation, extra heavy oil extraction, and mine safety, health and hazards engineering.

**Grzegorz Galecki**, Emeritus

PHD Wroclaw Tech University, Poland

System integration, modeling of mining processes supported by waterjets, novel methods of comminution, particulate processing, coal conversion into fuels, borehole mining, mineral processing.

**Catherine Johnson**, Assistant Professor

PHD University of Kentucky

Environmental Considerations of blasting, fragmentation prediction, biological effects of shock exposure, explosibility of dusts.

**Braden Lusk**, Lecturer<sup>1</sup>

PHD University of Missouri-Rolla

**Kyle Perry**, Associate Professor<sup>1</sup>

PHD University of Kentucky

Explosion protection, mine blasting effects, dust explosions, ground control.

**Taghi Sherizadeh**, Assistant Professor

PHD University of Arizona

Computational mechanics; numerical, statistical, and probabilistic modeling in rock mechanics; rock slope stability and stability of underground excavations; application of numerical modeling in underground and surface mining; reservoir geomechanics (Wellbore stability, Hydraulic fracturing, and Sand production); geomechanical aspects of CO2 sequestration; geothermal Energy recovery; assessment of nuclear waste disposal sites; pore pressure and in-situ stress analysis; compaction and subsidence modeling, artificial Intelligence (artificial neural networks, fuzzy logic and genetic algorithms).

**Paul Nicholas Worsey**, Professor Emeritus<sup>1</sup>

PHD University of Newcastle-upon-Tyne, United Kingdom

Explosives engineering, drilling and blasting, rock excavation, demolition, commercial pyrotechnics.

**Guang Xu**, Associate Professor

PHD Virginia Tech

Mine ventilation, health and safety; mining-induced particulate matter (PM) monitor and control, underground fire safety, computational fluid dynamics (CFD), enhanced coalbed methane recovery using microwave technology.

**MIN ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

**MIN ENG 5001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MIN ENG 5113 Mine Atmosphere Control** (LAB 1.0 and LEC 2.0)

Fundamentals of mine ventilation, including the principles of airflow, control of gases, dust, and temperature, methane drainage, mine fans, network theory, computer network simulation, and economics of airflow, with emphasis on analysis, systems design and practical application. Prerequisite: Mech Eng 2527 and Civ Eng 3330; or Nuc Eng 3221.

**MIN ENG 5212 Aggregates and Quarrying** (LEC 3.0)

Advanced coverage of topics on the stone and aggregate industry, including surface and underground operations, plant equipment, economics, marketing, transportation, and environmental topics. The course will include at least one field trip and a design project. Prerequisite: Min Eng 3912; Preceded or accompanied by Civ Eng 3116.

**MIN ENG 5322 Coal Mining Methods** (LEC 3.0)

An in-depth study of all aspects of coal mining, including an overview of the coal industry, reserves and geology, planning and development of coal mines, surface and underground mechanized methods of face preparation, equipment, coal extraction, handling and preparation as practiced in the United States. Prerequisites: Min Eng 5912.

**MIN ENG 5412 Aggregates Materials Sizing and Characterization** (LAB 1.0 and LEC 2.0)

Geological formation of aggregates; aggregate properties and their measurements; aggregates for specific end-user applications; specifications and standards; processing (crushing, screening, classification, and washing); plant design and flow sheet analysis; quality control and assurance. Field trip to a nearby quarry required. Prerequisite: Min Eng 2412.

**MIN ENG 5413 Material Processing by High Pressure Water Jet** (LEC 3.0)

Methods of generating high pressure water jets; standard equipment, existing techniques and basic calculations. Applications of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. (Co-listed with Mech Eng 5606).

**MIN ENG 5422 Coal Preparation** (LEC 2.0 and LAB 1.0)

Coal properties, sampling, testing, breaking, sizing, cleaning and dewatering. Disposal of refuse. Prerequisite: Min Eng 2412.

**MIN ENG 5423 Flotation and Hydrometallurgy** (LEC 2.0 and LAB 1.0)

Forth flotation including mineral surfaces, double layer theory, zeta potential, hydrophobicity, adsorption, collectors, frothers, modulation, kinetics, and sulphide and acid flotation systems. Hydrometallurgy including leaching, ion exchange and liquid/liquid extraction. Prerequisites: Min Eng 2412.

**MIN ENG 5424 Mineral Processing II Mechanics And Design** (LEC 2.0 and LAB 1.0)

Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisites: Min Eng 2412. (Co-listed with Met Eng 5270).

**MIN ENG 5522 Ore Reserve Analysis and Geostatistics** (LAB 1.0 and LEC 2.0)

Principles of geostatistics, theory of spatially correlated random variables, variance and co-variances and their application on the evaluation of mineral resources, ore reserve estimation, strategic exploration, and production planning. Real case studies from mining industry will be presented. Prerequisites: Math 3304; Stat 3113 or Stat 3115.

**MIN ENG 5532 Advanced Mining Economics** (LEC 3.0)

Mining industry & national economics. Social & economics significance of mined commodities. Marketing of mined commodities. Innovation approaches to mine financing, project loans, and leasing. Mining feasibility studies, government influence & policy, mining industry foreign investment, investment strategies, mining taxation, cost predictions. Case Studies.

**MIN ENG 5612 Principles of Explosives Engineering** (LAB 1.0 and LEC 2.0)

Theory and application of explosives in the mining industry; explosives, initiating systems, characteristics of explosive reactions and rock breakage, fundamentals of blast design, drilling and blasting, regulatory and safety considerations. Prerequisites: Min Eng 2126; successful background check. (Co-listed with Exp Eng 5612).

**MIN ENG 5622 Blasting Design And Technology** (LAB 1.0 and LEC 2.0)

Advanced theory and application of explosives in excavation; detailed underground blast design; specialized blasting including blast casting, construction and pre-splitting. Introduction to blasting research. Examination of field applications. Prerequisites: Min Eng 5612. Student must be at least 21 years of age. Successful background check. (Co-listed with Exp Eng 5622).

**MIN ENG 5742 Environmental Aspects of Mining** (LEC 3.0)

Permitting: the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, nonmetal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Prerequisites: Preceded or accompanied by Min Eng 5933 or Geo Eng 5441 or Env Eng 5619. (Co-listed with Geo Eng 5276).

**MIN ENG 5822 Strata Control** (LEC 3.0)

A detailed review of artificial ground support, both above and below ground, including slope stabilization techniques and shaft and tunnel liner design. The use of shotcrete, roofbolts, and solid liners and the principles of underground longwall and room and pillar mine support. Longwall and hydraulic mining practice is covered. Prerequisite: Min Eng 4823.

**MIN ENG 5823 Rock Mechanics** (LEC 2.0 and LAB 1.0)

Applications of the fundamental principles of mechanics to engineering problems of equilibrium, strength and stiffness of rock materials. Review of in-situ stresses, laboratory and field instrumentation, rock and rockmass properties. Ground Control; pillar design, roof span design, rock reinforcement, surface subsidence, slope stability, and violent failure. Prerequisites: Physics 2135; Civ Eng 2210; Geology 3310. Field trip required.

**MIN ENG 5912 Mine Power and Drainage** (LEC 2.0 and LAB 1.0)

Engineering principles of mine power distribution and application and mine dewatering. Basics of electrical circuits, AC/DC power, transformers, electric meters, power distribution, and power management. Hydraulic power systems. Compressed air in mines. Mine dewatering. Controlling water inflow. Dewatering wells. Water pumping and pumping systems. Prerequisite: Mech Eng 2527 and Civ Eng 3330; or Nuc Eng 3221.

**MIN ENG 5913 Advanced Computer Aided Mine Design** (LEC 2.0 and LAB 1.0)

Project-based mine planning and design course. Engineering design process applied to computer-aided mine planning and design. Mine layouts, production planning, and materials scheduling optimization. Prerequisite: Graduate standing.

**MIN ENG 5922 Tunneling & Underground Construction Techniques** (LEC 2.0 and LAB 1.0)

Mechanical and conventional excavation techniques in underground tunneling and construction. Topics include tunneling layouts design, equipment and performance modeling, ground control systems including support, drainage, and structural integrity. Construction specifications, advance rate and contractual and cost estimation. Prerequisite: Consent of instructor. (Co-listed with Exp Eng 5922).

**MIN ENG 5932 Underground Mining Methods** (LEC 3.0)

Principles of planning, constructing, and operating economically viable underground mines. Cost effective mining methods: room-and-pillar, sublevel open stoping, VCR, shrinkage, sublevel caving, cut-and-fill, block caving, longwall. Selection of equipment for underground mining operations. Optimization of mine performance. Field trip Required. Prerequisite: Preceded or accompanied by Min Eng 3913.

**MIN ENG 5933 Surface Mining Methods** (LEC 3.0)

Principles of planning, constructing, and operating economically viable surface mines. Cost effective mining methods: placer mining, strip mining, open pit mining, quarrying. Selection of equipment for surface mining operations. Optimization of mine performance. Field trip required. Prerequisites: Min Eng 3912; Min Eng 3512; preceded or accompanied by Min Eng 5823.

**MIN ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MIN ENG 6001 Special Topics** (LAB 1.0 and LEC 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MIN ENG 6010 Seminar** (RSD 1.0)

Discussion of current topics.

**MIN ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MIN ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MIN ENG 6080 Graduate Project** (IND 3.0)

Advanced engineering design, experimentation, evaluation and assessment leading to the preparation of a project report. For practicing professionals, this project could be based on an actual industry problem. Prerequisites: Graduate Standing.

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**MIN ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**MIN ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MIN ENG 6132 Advanced Mine Health And Safety Design** (LEC 3.0)

Principles of design of mining operations with emphasis on the health and safety of the worker. Prerequisite: Graduate standing.

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**MIN ENG 6133 Mine Atmospheric Control II** (LEC 3.0)

Climatic measurements and temperature precalculations, emergency plans for fan failures and mine fires, mine air contaminants, mine noises, mine dust, refrigeration and cooling plant layout, radiation control. Prerequisite: Min Eng 4113.

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**MIN ENG 6432 Advanced Mineral Engineering Design II** (LEC 1.0 and LAB 2.0)

Incorporation of principles developed in Min Eng 6132 in advanced design projects for mineral plants and systems, with emphasis on environmental protection, health, and safety. Prerequisite: Min Eng 6132.

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**MIN ENG 6522 Mining Property Feasibility Studies And Evaluation Procedure** (LAB 1.0 and LEC 2.0)

A systematic phased approach is presented, designed to increase the level of confidence and accuracy of estimates, moving from exploration through to a "bankable" study. Liability, ethics, resource/reserves, political/social/investment risk, economic parameters, and due diligence are discussed. Prerequisite: Min Eng 3512 or Geology 3511 or Min Eng 4742 or Geophys 3251.

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**MIN ENG 6532 Mine Management II** (LEC 3.0)

The course covers advanced concepts in managing mine operations. Topics to be covered include TQM, statistical process control, benchmarking, KPI, standards and standardization, ISO 9000: Quality Control, ISO 14000: Environmental systems, OHSAS 18000. Management systems, SA8000, Social Accountability and others. Prerequisite: Consent of instructor.

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**MIN ENG 6622 Environmental Controls For Blasting** (LAB 1.0 and LEC 2.0)

Advanced blast mechanics; overbreak control including comprehensive coverage of perimeter and smoothwall specialist blasting techniques and geotechnical factors affecting blast vibration, limits analysis monitoring and control; air blast control including limits, monitoring and atmospheric and topographic effects. Prerequisites: Min Eng 5612, Successful background check. (Co-listed with Exp Eng 6412).

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**MIN ENG 6632 Theory Of High Explosives** (LEC 3.0)

Study of the application of chemical thermodynamics and the hydrodynamic theory to determine the properties of high explosives; application of detonation theory to steady-state detonations in real explosives; application of the above to the blasting action of explosives. Prerequisite: Graduate Standing. (Co-listed with Exp Eng 6212).

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**MIN ENG 6712 Managing Social and Environmental Risks in Mining (Intro to Responsible Mining)** (LEC 3.0)

This course is an introduction to responsible mining. It focuses on industry and NGO programs around sustainability and reporting in mining, financial community response, community of interest engagement and participation, and safety and crisis response and management. Prerequisites: Min Eng 4742 or Min Eng 5742.

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**MIN ENG 6735 Sustainability In Mining** (LEC 3.0)

Sustainability defined: social, economic and environmental impacts. Mining as sustainable development interventions. Mine planning for sustainability, sustainability assessment and reporting, sustainable mine closure and post-mining land use. Case studies. Prerequisite: Min Eng 4742.

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**MIN ENG 6842 Advanced Rock Mechanics** (LEC 3.0)

Advanced topics in static and dynamic rock mechanics; elasticity theory, failure theories and fracture mechanics applied to rock; stress wave propagation and dynamic elastic constants; rock mass classification methods for support design; pillar design in coal and metal mines; introduction to numerical models. Prerequisite: Min Eng 5823 or Civ Eng 3715.

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**MIN ENG 6843 Dynamic Rock Mechanics** (LEC 3.0)

Advanced topics in dynamic rock mechanics. Stress wave propagation in the earth, dynamic elastic constants in isotropic and anisotropic rock, Hopkinson bar impact analysis, spallation and radial fracturing caused by stress pulses, shock wave generation in rock by explosives, shock wave propagation and effects. Prerequisite: Min Eng 5823 or Civ Eng 3715.

**MIN ENG 6912 Simulation of Mining Systems** (LEC 3.0)

Overview of stochastic simulation. Model formulation using general purpose process simulation software. Model verification and validation. Simulation experimentation. Prerequisites: Graduate standing or Stat 5643.

**MIN ENG 6922 Optimization Applications In Mining I** (LEC 3.0)

Mining applications of deterministic optimization techniques are covered, including linear, integer, mixed-integer, dynamic, unconstrained and constrained nonlinear, and heuristic programming. Prerequisite: Graduate standing or consent.

**MIN ENG 6923 Geostatistics** (LEC 3.0)

Definition of geostatistical data; theory of random fields; autocorrelation and measures of spatial variability including semivariograms, variograms and covariance functions; and spatial prediction and validation. Case studies in mineral resource estimation and environmental pollutant prediction will be presented. Prerequisites: Graduate standing or consent of instructor.

**MIN ENG 6932 Advanced Mining Systems** (LEC 3.0)

Principles of design for the development and production of hard rock mineral deposits that require integrated surface and underground mining methods. Cost considerations leading to optimization. Terminal feasibility report required. Prerequisites: Min Eng 4932 and Min Eng 4933.

**MIN ENG 6935 Underground Mine Design** (LEC 3.0)

This course will focus on the determinants of underground mine design, geomechanical mine design for underground mining; mine optimization; mine environmental systems; and underground mine design and optimization. Prerequisite: Min Eng 4932 or equivalent.

**MIN ENG 6936 Surface Mine Design** (LEC 3.0)

This course will focus on the determinants of surface mine design, geomechanical and geometrical mine design for open pit and strip mining; mine layouts optimization; mine environmental systems; and research directions in surface mine design and optimization. Prerequisite: Min Eng 4933 or equivalent.

**MIN ENG 6992 Research Methods** (LEC 3.0)

Foundations, dimensions, and methods for designing and investigating research problems. Focus on fundamentals and applied research, research methods, literature review, experimental design and experimentation, dissertation composition, concepts of originality and intellectual property. Prerequisites: PhD students only. (Co-listed with Exp Eng 6292).

## Nuclear Engineering

The nuclear engineering graduate program offers the master of science, the doctor of engineering, and the doctor of philosophy degrees. B.S. in

a field of engineering or suitable physical science is a prerequisite for admission into the nuclear engineering graduate program. The master's degree program is designed to provide training and expertise in the design of nuclear energy systems, use of nuclear technology for medical as well as industrial applications. Both thesis and without thesis options are available for M.S. degree program with a minimum of 30 credit hours required for successful completion. Research areas of specialization include:

- Reactor design and safety
- Thermal hydraulics
- Radiation effects
- Radiation dosimetry, protection and health physics
- Radiation transport and shielding
- Space nuclear power
- Materials for nuclear applications
- Nuclear fuel cycle
- Radioactive waste management
- Radiation imaging and its applications in medicine and industry
- Radiation measurements and spectroscopy

For the Ph.D. program, a research project with a written dissertation of high caliber demonstrating candidate's capacity to conduct independent and original research, to critically analyze results and to infer sound conclusions is necessary. The dissertation must produce original research results acceptable for publication in a refereed journal. To facilitate high quality research, the nuclear engineering program has the following laboratory facilities:

### Nuclear Reactor

The Missouri University of Science and Technology Nuclear Reactor (MSTR) is a Nuclear Regulatory Commission (NRC) licensed 200 kW pool-type reactor that is used to support the engineering and science activities on campus. Using the facility, the reactor staff provides hands-on laboratory, research and development and project opportunities. The reactor itself uses uranium fuel and is cooled by natural convection in a pool containing approximately 30,000 gallons of water.

The open pool design allows access to the reactor core where experiments and samples to be irradiated can be positioned. The facility is equipped with a pneumatics sample irradiation system, a neutron beam port that provides a collimated neutron beam, and a thermal column.

### Internet-Accessible Hot Cell Facility

A dual-chambered internet-accessible heavily shielded facility with pneumatic access to the Missouri S&T 200 kW Research Nuclear Reactor (MSTR) allows authorized distance users to remotely manipulate and analyze neutron irradiated samples. The system consists of two shielded compartments, one for multiple sample storage, and the other dedicated exclusively for radiation measurements and spectroscopy. The second chamber has multiple detector ports, with graded shielding, and has the capability to support gamma spectroscopy using radiation detectors such as an HPGe detector. Both these chambers are connected through a rapid pneumatic system with access to the MSTR nuclear reactor core. The total transportation time between the core and the hot cell is less than 3.0 seconds.

## Radiation Measurement and Spectroscopy Laboratory (RMSL)

The Radiation Measurement and Spectroscopy Laboratory is equipped for measurement of alpha, beta and gamma particles with the help of various detectors such as Geiger-Mueller counters, NaI (TI) scintillation detectors, HPGe Semiconductor detectors, Ortec Ultra charged particle detectors, and Ortec partially depleted silicon surface barrier detectors. Detection systems including pre-amplifiers, amplifiers, single channel analyzers, counters, timers, multi-channel analyzers are also included in the laboratory. RMSL contains neutron and X-ray measurement modules using He-3 isotropic detectors and ion chambers respectively. All of the detectors in RMSL are compatible with state-of-the-art software and Lynx digital data analysis systems which allows remote web-based experimental capability. All of these things allows the RMSL tremendous potential for collaborative experiments and discoveries with local researchers and researchers around the world.

## Nuclear Materials Laboratory

The facilities of the Materials Research Center, metallurgical engineering, and nuclear engineering programs are also available for nuclear materials-related research. These facilities include state of the art SEM/EDX, TEM, STEM, FIB/FESEM, and XRD.

## Computer Laboratory

Students have the opportunity to use large computer codes commonly used in the nuclear industry for reactor core design, radiation transport, and thermal hydraulics analysis. The nuclear engineering program maintains an excellent laboratory with personal computers with access to a campus cluster of numerically intensive computing (NIC) systems.

## Two-phase Flow and Thermal-Hydraulics Laboratory (TFTL)

The nuclear engineering TFTL is designed to perform both fundamental and advanced two-phase flow experiments simulating prototypic nuclear reactor conditions. The TFTL is equipped with state-of-the-art instrumentation such as a micro multi-sensor conductivity probe, a high-speed digital motion-corder, various flow measurement devices, and a data acquisition system and software. Topics of research studied in the TFTL include advanced two-phase flow modeling, two-phase flow characterization in various flow channel geometries, air-water two-phase bubble jet experiment, secondary flow analysis in liquid film flow, and development of two-phase flow instrumentation.

## Advanced Radiography and Tomography Lab

The laboratory is designed to perform radiation imaging for medical or industrial purpose. Students have opportunities of running Monte Carlo simulation codes for radiation imaging systems and experimenting with digital x-ray radiography, x-ray computed tomography, neutron imaging, etc. The technologies developed in the lab can be applied to either medical imaging or non-destructive inspection of various materials or objects.

## Neutron Generator Laboratory

The neutron generator laboratory has a D-D neutron generator that produces approximately  $10^9$  neutrons/sec. The neutron generator is available for both graduate and undergraduate research and education

at Missouri S&T. Examples of research using the neutron generator are reactor kinetics research, the study of two-phase flow, research in nuclear forensics and radiochemistry, particle tracking in complex flows, and the photon-neutron tomography for mechanical testing of structural materials.

## Nuclear Nonproliferation

The nuclear engineering program offers a graduate certificate program to professionals and students who desire to undergo formal instruction in nuclear nonproliferation. The topics in comprising the certificate program are selected from courses available to graduate students in the nuclear engineering program at Missouri University of Science and Technology. All courses are available both in traditional on-campus delivery and online format. The certificate program deployment strategy allows all enrollees to pace their study in manner consistent with the individual's plans.

The Graduate Certificate in Nuclear Nonproliferation is open to all persons holding a B.S., M.S., or Ph.D. degree in Engineering, Science, and/or Mathematics as well as related B.A. or M.A. degrees, or are currently accepted into a graduate degree program at Missouri S&T.

### Curriculum

The certificate program requires 4 courses equivalent to 12 credit hours.

There are 8 course available to the certificate program, 1 of which is required for the completion of the graduate certificate in nuclear nonproliferation. Program enrollees may select any 3 of the remaining 7 courses towards the completion of the graduate certificate. Enrollees may take 1 or 2 classes each semester so that the certificate program may be completed within 1 to 2 years.

#### Required Course:

NUC ENG 5509	Nuclear Nonproliferation	3
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#### Elective Courses:

NUC ENG 5207	Nuclear Fuel Cycle	3
NUC ENG 5281	Probabilistic Risk Assessment I	3
NUC ENG 5312	Nuclear Radiation Measurements and Spectroscopy	3
NUC ENG 5347	Radiological Engineering	3
NUC ENG 5577	Advanced Nuclear Forensics and Radiochemistry	3
NUC ENG 5507	Nuclear Policy	3
NUC ENG 6331	Radiation Shielding	3

#### Muthanna Hikmat Al Dahhan, Professor

DSc Washington University

Multiphase reaction and reactor engineering flow systems; transport-kinetic integration; advanced measurement and computational techniques; applications to green technology and sustainable development in energy, products, and environment.

#### Ayodeji Babatunde Alajo, Associate Professor

PHD Texas A&M University

High fidelity nuclear systems design and modeling, advanced fuel cycles, radioactive waste management, and nuclear systems safety.

#### Carlos Henry Castano, Associate Professor

PHD University of Illinois Urbana-Champaign

Plasma material interactions and vacuum breakdown, nuclear materials, and radiochemistry.

#### Arvind Kumar, Professor Emeritus

PHD University of California-Berkeley

Nuclear materials, radiation damage, and mechanical properties.

**Hyoung Koo Lee**, Associate Professor  
PHD University of California-Berkeley  
Radiation imaging systems (x-ray, gamma, and neutron), digital image processing and CT reconstruction, medical and industrial applications of radiation imaging.

**Xin Liu**, Associate Professor  
PHD University of Wisconsin-Madison  
Radiation detection and measurement, medical imaging system, Monte Carlo simulation, advanced nuclear energy system design.

**Gary Edward Mueller**, Associate Professor<sup>1</sup>  
PHD University of Missouri-Rolla  
Nuclear power safety analysis, heat transfer and fluid flow, packed bed characteristics.

**Joshua P Schlegel**, Assistant Professor  
PHD Purdue University  
Two-phase flows, interfacial area transport, heat transfer and fluid mechanics, nuclear reactor safety.

**Joseph D Smith**, Professor and Laufer Endowed Chair in Energy  
PHD Brigham Young University  
Laufer Chair of Energy. Hybrid energy generation, gas flare design, process modeling, and control.

**Shoaib Usman**, Associate Professor  
PHD University of Cincinnati  
Turbulence and dispersion, environmental radon measurement, radiation measurement and effects on materials, and radiation interaction with fluids.

**Haiming Wen**, Assistant Professor  
PHD University of California-Davis

**NUC ENG 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**NUC ENG 5001 Special Topics** (IND 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**NUC ENG 5203 Reactor Physics I** (LEC 3.0)  
Study of neutron interactions, fission, chain reactions, neutron diffusion and neutron slowing down; criticality of a bare thermal homogeneous reactor. Prerequisite: Nuc Eng 3205.

**NUC ENG 5207 Nuclear Fuel Cycle** (LEC 3.0)  
Nuclear fuel reserves and resources; milling, conversion, and enrichment; fuel fabrication; in-and-out-of core fuel management; transportation, storage, and disposal of nuclear fuel; low level and high level waste management; economics of the nuclear fuel cycle. Prerequisite: Nuc Eng 3205.

**NUC ENG 5241 Nuclear Materials I** (LEC 3.0)  
Fundamentals of materials selection for components in nuclear applications; design and fabrication of UO<sub>2</sub> fuel; reactor fuel element performance; mechanical properties of UO<sub>2</sub>; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110. (Co-listed with Met Eng 5170).

**NUC ENG 5251 Reactor Kinetics** (LEC 3.0)  
Derivation and solutions to elementary kinetics models. Application of the point kinetics model in fast and thermal reactor dynamics, internal and external feedback mechanisms, rigorous derivation and solutions of the space dependent kinetics model fission product and fuel isotope changes during reactor operation. Prerequisite: Nuc Eng 3205.

**NUC ENG 5257 Introduction to Nuclear Thermal Hydraulics** (LEC 3.0)  
An introductory course in the application of thermal-hydraulic principles to energy systems, with emphasis on nuclear energy issues. Will include the development of constitutive models and applications to power systems, fluid mechanics, and heat transfer problems (including multiphase flows). Prerequisite: Graduate standing.

**NUC ENG 5281 Probabilistic Risk Assessment I** (LEC 3.0)  
A study of the techniques for qualitative and quantitative assessment of reliability, safety and risk associated with complex systems such as those encountered in the nuclear power industry. Emphasis is placed on fault tree analysis. Prerequisite: Nuc Eng 3205.

**NUC ENG 5312 Nuclear Radiation Measurements and Spectroscopy** (LAB 1.0 and LEC 2.0)  
Contemporary radiation detection theory and experiments with high resolution gamma-ray spectroscopy, solid state detectors, neutron detection and conventional gas filled detectors. Neutron activation analysis of unknown material, statistical aspects of nuclear measurements. Prerequisite: Nuc Eng 3205.

**NUC ENG 5347 Radiological Engineering** (LEC 3.0)  
Radiation exposure pathways analysis. Modeling of radionuclides transport through atmosphere, surface and ground water. Human health impact. Transportation of nuclear waste. Nuclear Waste characterization. Regulatory structure and requirements. Scenario case studies and computer simulation of transport. Prerequisite: Nuc Eng 3205.

**NUC ENG 5350 Advanced Nuclear Medical Science** (LEC 3.0)  
Advanced level of technologies involved in medical modalities, such as digital radiography, digital mammography, modern computed tomography, gamma camera, SPECT and PET will be covered. Prerequisites: Nuc Eng 4312 or equivalent.

**NUC ENG 5363 Applied Health Physics** (LEC 3.0)  
Radiation sources; external and internal dosimetry; biological effects of radiation; radiation protection principles; regulatory guides; radioactive and nuclear materials management. Prerequisite: Nuc Eng 3103 or Physics 2305.

**NUC ENG 5365 Radiation Protection Engineering** (LEC 3.0)

Radiation fields and sources including nuclear reactors, radioactive wastes, x-ray machines, and accelerators. Stopping of radiation (Charges particles, photons, and neutrons) by matter. Radiation transport methods. Radiation shielding design. Dose rate calculations. Biological effects of radiation. Regulatory guides (10CFR20). Prerequisite: Nuc Eng 3205.

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**NUC ENG 5367 Radioactive Waste Management And Remediation** (LEC 3.0)

Sources and classes of radioactive waste, long-term decay, spent fuel storage, transport, disposal options, regulatory control, materials issues, site selection and geologic characterization, containment, design and monitoring requirements, domestic and foreign waste disposal programs, economic and environmental issues, history of disposal actions, and conduct of remedial actions and clean up. Prerequisite: Math 3304. (Co-listed with Geology 4421).

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**NUC ENG 5370 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Mech Eng 5570, Physics 4543).

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**NUC ENG 5428 Reactor Laboratory I** (LEC 1.0 and LAB 1.0)

Acquaints the student with neutron flux measurement, reactor operation, control rod calibration, reactor power measurement and neutron activation experiments. Experiments with the thermal column and neutron beam port are also demonstrated. Prerequisites: Nuc Eng 4312, 3205.

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**NUC ENG 5438 Reactor Laboratory II** (LEC 1.0 and LAB 1.0)

A continuation of Nuclear Engineering 304 with experiments of a more advanced nature. Prerequisite: Nuc Eng 4428.

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**NUC ENG 5456 Reactor Operation II** (LAB 1.0)

The operation of the training reactor. The program is similar to that required for the NRC Reactor Operator's license. Students from other disciplines will also benefit from the course. Prerequisite: Nuc Eng 2105, 2406.

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**NUC ENG 5507 Nuclear Policy** (LEC 3.0)

This course introduces nuclear security and safeguards policy. It explores the following topics: history of domestic and international nuclear policy, evolution of U.S. nuclear weapons policy, factors influencing policy, the IAEA, nuclear deterrence policy, nuclear safeguards policy, policy in non-proliferation issues, and various international agreements. Prerequisites: Graduate Standing or enrolled in the Nuclear Nonproliferation certificate program.

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**NUC ENG 5509 Nuclear Nonproliferation** (LEC 3.0)

This course will introduce IAEA mission specific to nonproliferation. The class will provide discussion of essential elements of a nuclear weapon, followed by a brief historical over of nonproliferation treaties in place to deter proliferation. Methods of fissile material production will be discussed followed by a survey of tool and techniques available an Prerequisites: Graduate Standing or enrolled in the Nuclear Nonproliferation certificate program.

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**NUC ENG 5577 Advanced Nuclear Forensics and Radiochemistry** (LEC 3.0)

Fundamentals of radiochemistry, including nuclear science, cosmochemistry, spent fuel reprocessing, with details on solvent extraction. We will review case studies in Nuclear Forensics. This advanced section also includes experiments on radiochemistry and demonstrate experimental nuclear forensics techniques. Dual listed with Nuc Eng 4577.

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**NUC ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**NUC ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**NUC ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**NUC ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**NUC ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**NUC ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**NUC ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**NUC ENG 6203 Advanced Reactor Physics** (LEC 3.0)

Transport and diffusion theory; multigroup approximation; criticality calculations; cross-section processing; buildup and depletion calculations; delayed neutrons and reactor kinetics; lattice physics calculations; full core calculations; analysis and measurement of reactivity coefficients. Prerequisite: Math 5325.

**NUC ENG 6205 Linear Transport Theory** (LEC 3.0)

Monoenergetic Boltzmann equation for neutral particles by the method of singular eigen-functions and polynomial expansions. Prerequisites: Nuc Eng 4203, Math 5358.

**NUC ENG 6223 Nuclear Reactor Safety** (LEC 3.0)

Study of safety criteria; reactor characteristics pertinent to safety; reactor transient behavior; loss of coolant accident analysis; emergency core cooling; fuel behavior during accident conditions; reactor risk analysis; current reactor safety issues. Prerequisites: Nuc Eng 4203 and 3229.

**NUC ENG 6241 Effects Of Radiation On Solids** (LEC 3.0)

The theories of the interaction of nuclear radiation with matter. Experimental approaches to radiation studies, including the sources and dosimetry. Nature and properties of crystal imperfections. The influence of radiation on physical, mechanical and surface properties of metals and alloys. Radiation effects on materials other than those incorporated in nuclear reactors. The annealing of defects. Prerequisite: Met Eng 5170.

**NUC ENG 6257 Advanced Nuclear Thermal Hydraulics** (LEC 3.0)

Treatment of advanced topics in nuclear reactor thermal-hydraulics including analysis of fuel elements and fuel melting, multiphase flow dynamics and two-fluid models, interfacial transfer of mass, momentum, and energy, multiphase flow scaling, and numerical applications. Prerequisite: Math 5325.

**NUC ENG 6325 Plasma Physics** (LEC 3.0)

Fundamentals of kinetic, theory, fluid equations, MHD equations, and applications: wave propagation, shielding effect, diffusion, stability, and charged particle trajectories. Prerequisite: Nuc Eng 4361 for Nuc Eng; Physics 4211 for Physics.

**NUC ENG 6331 Radiation Shielding** (LEC 3.0)

Radiation sources; interactions of radiation with matter; dosimetry and radiation protection guidelines. The particle transport equation and methods of solving it; the Monte Carlo Method; special computational methods for neutron and gamma attenuation. Computer codes used in shielding. Shielding materials, shield design. Prerequisite: Nuc Eng 4203.

## Petroleum Engineering

The petroleum engineering program offers courses of study leading to the masters of science, doctor of philosophy, or doctor of engineering degrees. The master's degree can be earned with either a thesis option or a non-thesis option.

While the program encourages students with an undergraduate degree in petroleum engineering to pursue graduate study, many graduate students are accepted with backgrounds in other areas of engineering, such as chemical engineering, mechanical engineering, or geological engineering. The program accepts such students with the expectation that any remedial petroleum engineering coursework will be met by the student

while in residence for the master's degree. Students with backgrounds in geology or geophysics will also need to complete all fundamental engineering courses required for a degree in engineering.

Graduate students studying for a masters degree with a thesis option typically find support for their study depending on current research projects and the availability of funding. Students preferring the non-thesis option are typically self-funding for their masters degree.

Each student's graduate degree program is designed around a set of core petroleum engineering courses and other courses selected to support the thesis topic of interest. Students identify their thesis topic by the end of their first semester.

Research specialties of the petroleum engineering program include reservoir enhancement, hydraulic fracturing, CO2 sequestration, gel treatments, drilling, well completion performance studies, and geomechanics of petroleum recovery.

The program emphasizes mechanical earth modeling (MEM) as a specialty. The MEM group owns part of the university numerical intensive computing cluster. Students with a strong background in geological engineering and geomechanics will likely find excellent opportunities for advanced studies.

The petroleum engineering laboratories contain modern equipment designed to study the many problems encountered in oil and gas production, as well as support research. The department laboratories include gas porosimeter and permeameter, liquid permeameter, viscometers, tensiometers, and a HPTP core flooding cell. The program also utilizes departmental facilities that include core cutting and preparation, laser ablation, XRD, SEM, and a triaxial and fracture cell and a direct shear apparatus for determining rock and fracture properties.

Students externally supported by international oil and gas operating companies may also suggest research topics related to their professional experience or special topics of interest to their companies.

Suggested minimum GRE scores: Q150 and A(W) 3.0 and (verbal score + quantitative score = 300)

For additional information regarding graduate study opportunity contact [rocks@mst.edu](mailto:rocks@mst.edu). Additional information may also be found at the web pages at: <http://gse.mst.edu/> or <http://petroleum.mst.edu/>.

**Baojun Bai**, Professor

PHD New Mexico Institute of Mining

Lester Birbeck Chair. Conformance control, enhanced oil recovery (EOR), numerical modeling and reservoir simulation, multiple-phase fluid flow in porous media, unconventional oil and gas development, and carbon sequestration.

**Shari Dunn Norman**, Associate Professor

PHD Heriot-Watt University

Well completions, including completion reliability and benchmarking, well stimulation, well productivity, production engineering and offshore operations.

**Andreas Eckert**, Associate Professor

PHD University of Karlsruhe

Mechanical earth modeling, finite element methods in petroleum engineering, petroleum geomechanics and geophysics.

**Ralph E Flori Jr**, Associate Professor  
PHD University of Missouri-Rolla  
Engineering mechanics, mechanical earth modeling, reservoir engineering, reservoir simulation, engineering education.

**Abdulmohsin Imqam**, Assistant Professor  
PHD Missouri University of Science and Technology  
Enhanced oil recovery from unconventional and conventional resources, hydraulic fracturing, wellbore integrity.

**Mingzhen Wei**, Assistant Professor  
PHD New Mexico Tech  
Reservoir simulation, reservoir engineering, data modeling, data management, and advanced application development using artificial intelligence computation in the Petroleum Engineering.

**PET ENG 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects of projects in the department. Consent of instructor required.

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**PET ENG 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**PET ENG 5010 Seminar** (RSD 0.0-6.0)  
Discussion of current topics.

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**PET ENG 5040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**PET ENG 5085 Internship** (IND 0.0-15)  
Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**PET ENG 5099 Research** (IND 0.0-12)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**PET ENG 6000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects of projects in the department. Consent of instructor required.

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**PET ENG 6001 Special Topics** (LEC 2.0 and LAB 1.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

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**PET ENG 6010 Seminar** (IND 0.0-6.0)  
Discussion of current topics.

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**PET ENG 6040 Oral Examination** (IND 0.0)  
After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**PET ENG 6050 Continuous Registration** (IND 1.0)  
Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**PET ENG 6085 Internship** (IND 0.0-15)  
Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**PET ENG 6099 Research** (IND 0.0-12)  
Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**PET ENG 6211 Advanced Directional Drilling and MWD** (LEC 3.0)  
In-depth study of directional well planning and drilling. The course covers the bottom hole assemblies and operational techniques used in directional drilling as well as the limiting factors and hole problems related to horizontal wells. Advanced research topics and well design in directional drilling. Prerequisites: Pet Eng 4210.

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**PET ENG 6231 Drilling Optimization** (LEC 3.0)  
Optimization of the drilling process based on geomechanical model of the subsurface. Topics include drilling hydraulics, drilling bits, selection of operational parameters and analysis of drilling time and cost. Prerequisite: Pet Eng 4210.

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**PET ENG 6431 Advanced Well Completion Design** (LEC 3.0)  
Overview of hardware, fluids and processes employed in completing oil and gas wells. Types of well completions and design considerations. Downhole mechanics, tubing movement and stress calculations. Advanced concepts in well completion design and review of well completions literature. Prerequisites: Pet Eng 4410.

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**PET ENG 6441 Advanced Well Stimulation** (LEC 3.0)  
This course builds on the basic theory and fundamentals of hydraulic fracturing through the use of STIMPLAN software and hands on industry examples. The course teaches the methods used to plan, execute and evaluate hydraulic fracturing treatments. An advanced exercise and a research assignment are required. Students may not earn credit for both Pet Eng 4441 and Pet Eng 6441. Prerequisites: Pet Eng 3520 and Pet Eng 3310.

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**PET ENG 6521 Advanced Well Test Analysis** (LAB 1.0 and LEC 2.0)

Pressure transient analysis equations, well test analysis for fractured wells, horizontal wells, injection wells, and other special situations. Introduction to rate transient analysis. Prerequisites: Pet Eng 3520 and Pet Eng 4520.

**PET ENG 6541 Advanced Reservoir Engineering I** (LEC 3.0)

Advanced study of producing mechanisms. Prerequisites: Pet Eng 5631 and Pet Eng 4520.

**PET ENG 6551 Advanced Reservoir Engineering II** (LEC 3.0)

Flow through porous media: derivations and solutions for steady, semi-steady, and transient flow of single and multiple phase flow through porous media. Prerequisite: Pet Eng 3520.

**PET ENG 6621 Advanced Applied Reservoir Simulation** (LEC 3.0)

Advanced simulation of actual reservoir problems using both field and individual well models to determine well spacing, production effects of secondary and enhanced recovery processes, future rate predictions and recovery, coning effects, relative permeability adjustments and other history matching techniques. Prerequisite: Pet Eng 4621 or equivalent.

**PET ENG 6631 A Survey Of Improved Recovery Processes** (LEC 3.0)

An overview of current advanced recovery methods including secondary and tertiary processes. An explanation of the primary energy mechanism and requirements of these methods and an analysis of laboratory results and their subsequent field applications. Prerequisite: Pet Eng 4611.

**PET ENG 6711 Geodynamics** (LEC 3.0)

The applications of continuum physics to geological and petroleum engineering problems. Topics include plate tectonics, stress and strain in solids, elasticity and flexure, heat transfer, gravity, fluid mechanics, rock rheology, faulting, and flow in porous media. Prerequisites: Math 2222 and Geology 3310. (Co-listed with Geology 6211).

**PET ENG 6811 Advanced Offshore Petroleum Technology** (LEC 3.0)

A study of factors affecting offshore structural design and operation. Focus is on mobile offshore drilling units (MODUs). Subsea well systems and offshore pipelines are covered. Advanced topics in system design. Prerequisites: Pet Eng 4210, Civ Eng 3330, Civ Eng 2210.

## Physics

The department of physics offers programs leading to both the master of science and doctor of philosophy degrees. The master's degree can be earned with either a thesis or non-thesis option.

Most physics graduate students are supported by teaching or research assistantships, although some fellowships are available for exceptionally promising students. Most new graduate students start as teaching assistants in the introductory physics laboratory. Later, they are often supported as research assistants on external research grants. Entering graduate students usually have a physics undergraduate degree; however inquiries from students with other technical degrees and a good mathematics background are encouraged, since the program allows minor background deficiencies to be made up.

Each student's graduate degree program is designed around a set of core graduate courses (classical mechanics, electrodynamics, quantum

mechanics, and statistical mechanics) and two graduate physics electives. After their second year, Ph.D. students must take a qualifying examination based on the material taken from the undergraduate courses and the graduate core courses. Details of the program and course offerings can be found on the department's web page at <http://physics.mst.edu/> or requested via email to [physics@mst.edu](mailto:physics@mst.edu).

The department's research emphasis includes three areas of physics: condensed matter and materials physics; atomic, molecular, and optical physics; as well as astrophysics. Experimental and theoretical research opportunities are available in each of these areas. Graduate students in the department work with faculty on a wide range of problems, including the characterization of magnetic materials, predicting the properties of quantum and classical phase transitions, investigating electrical and thermal transport, determining electron-atom scattering events, computing the electronic structure of new materials, measuring and imaging ion-atom collisions, growing and characterizing exotic quantum materials, studying wave propagation in complex media, exploring quantum electrodynamics' descriptions of few-electron atoms and ions, studying gravitational waves emitted by black holes and neutron stars; and exploring the expansion history of the universe.

Most research is performed in the Physics Building, but several research studies are carried out in the Materials Research Center on campus as well as in national laboratories and other national facilities such as LIGO, the Laser Interferometer Gravitational-Wave Observatory. Special instrumentation in the physics department includes a unique ion-atom accelerator and energy-loss spectrometer, an optical atom trap, custom ultra-high vacuum systems, Auger and XPS surface characterization spectrometers, facilities for the growth of exotic materials, low temperature transport measurement instruments, and high-performance computer systems for modelling and simulation.

**Marco Cavaglia**, Professor

PHD International School for Advanced Studies, Trieste, Italy

**Aleksandr Chernatynskiy**, Assistant Professor

PHD University of Louisville

Theoretical condensed matter physics. Mechanical and transport properties of materials.

**Daniel Fischer**, Assistant Professor

PHD Heidelberg University

Experimental investigations of atomic fragmentation processes.

**Yew San Hor**, Associate Professor

PHD Rutgers University

Growth and characterization of exotic materials.

**Ulrich Jentschura**, Professor

PHD Dresden University of Technology

QED bound-state calculations, relativistic quantum dynamic process in laser fields, analysis of high-precision experiments.

**Anh Thu Le**, Assistant Professor

PHD Belarusian State University

**Don H Madison**, Curators Professor

PHD Florida State University

Theoretical studies of electron-atom collisions.

**Ioulia Y. Medvedeva**, Professor  
PHD Russian Academy of Science  
Theoretical condensed matter physics. First principles computational methods.

**Paul E Parris**, Professor  
PHD University of Rochester  
Theoretical condensed matter physics. Transport in disordered materials, photoelectronic polymers, polaron physics.

**Jerry L Peacher**, Professor  
PHD Indiana University Bloomington  
Theoretical atomic and molecular collisions.

**Shun Saito**, Assistant Professor  
PHD University of Tokyo, Japan

**Michael Schulz**, Curators Professor  
PHD University of Heidelberg  
Experimental atomic and molecular collisions.

**John G Story**, Associate Professor  
PHD University of Southern California  
Experimental atomic and molecular physics. Laser excitation of atoms.

**Steffen Thomas Vojta**, Curators Distinguished Professor  
PHD Chemnitz University of Technology, Germany  
Theoretical condensed matter and statistical physics. quantum and classical phase transitions, transport, and disorder.

**George D Waddill**, Professor  
PHD Indiana University Bloomington  
Experimental solid state physics. Surface physics and nano-scale magnetism.

**Gerald Wilemski**, Professor  
PHD Yale University  
Theoretical chemical physics, nucleation, aerosols, and neutron scattering.

**Alexey Georgiyevich Yamilov**, Associate Professor  
PHD The City University of New York  
Theoretical optical Physics. Wave propagation in complex media.

**PHYSICS 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PHYSICS 5001 Special Topics** (IND 0.0 and LEC 0.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 5333 Subatomic Physics** (LEC 3.0)  
An introduction to elementary particles. Topics include particle properties, nuclear forces, particle interactions, the Standard Model for quarks and leptons, fundamental forces in gauge field theory models, and the role of elementary particle interactions in cosmology. Prerequisite: Physics 3311.

**PHYSICS 5403 Computational Physics** (LEC 3.0 and LAB 1.0)  
An introduction to modern computer simulations for solving physics problems. The course will be project-oriented with examples including planetary motion, chaotic dynamics, quantum scattering, structure of atoms and clusters, molecular dynamics, and Monte-Carlo simulations. Prerequisites: Physics 2305 or Physics 2311; Math 3304; programming experience.

**PHYSICS 5413 Chaos, Fractals, and Nonlinear Dynamics** (LEC 3.0)  
An introduction into nonlinear dynamics, deterministic chaos, and fractals. Topics covered include phase plane analysis, iterated maps, routes to chaos, Lyapunov exponents, strange attractors and pattern formation with applications to chaotic vibrations, population dynamics, chemical oscillations and lasers. Prerequisites: Math 3304; Physics 2135 or Physics 2111.

**PHYSICS 5503 Fourier Optics** (LEC 3.0)  
Applications of Fourier analysis and linear system theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or Physics 4211. (Co-listed with ELEC ENG 5210).

**PHYSICS 5513 Fiber And Integrated Optics** (LEC 3.0)  
Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Elec Eng 5220).

**PHYSICS 5603 Advanced Physics Laboratory Teaching Methods** (LEC 3.0)  
Objectives, methods and problems related to teaching of introductory physics, with an emphasis on laboratory instruction, the development of educational laboratory experiments and techniques, student learning styles, student assessment, student work groups, computer-based data acquisition, and communication techniques. Prerequisite: Graduate standing.

**PHYSICS 6000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PHYSICS 6001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 6002 Coop Registration** (IND 0.0-1.0)  
Doctoral candidates participating in a cooperative program with another UM campus must enroll for one hour of credit for their first semester in the program and zero hours of credit for successive registration periods until degree is completed. Failure to do so may invalidate candidacy. Billing is automatic as is registration upon payment.

**PHYSICS 6010 Seminar** (RSD 0.0-6.0)  
Discussion of current topics.



**PHYSICS 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**PHYSICS 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**PHYSICS 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**PHYSICS 6101 Classical Mechanics I** (LEC 3.0)

Methods of Newton, Lagrange, and Hamilton applied to the motion of particles and rigid bodies. Introduction to canonical transformations and Poisson brackets. Classical scattering and small oscillations. Prerequisites: Math 3304 and Physics 3201.

**PHYSICS 6111 Electrodynamics I** (LEC 3.0)

A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations–Green's function, boundary value problems, multipoles, conservation laws. Prerequisites: Physics 4211.

**PHYSICS 6201 Quantum Mechanics I** (LEC 3.0)

Basic formalism applied to selected problems. Schrodinger equation and one dimensional problems, Dirac notation, matrix mechanics, harmonic oscillator, angular momentum, hydrogen atom, variational methods, introduction to spin. Prerequisite: Physics 4301 or equivalent.

**PHYSICS 6211 Electrodynamics II** (LEC 3.0)

A continuation of Physics 5211+D1067. Applications of time-dependent Maxwell's equations to such topics as plasmas, wave guides, cavities, radiation; fields of simple systems and multipoles. Relativity; covariant formulation of Maxwell's equations and conservation laws, fields of uniformly moving and accelerated charges. Prerequisite: Physics 5211.

**PHYSICS 6301 Quantum Mechanics II** (LEC 3.0)

Perturbation theory, treatment of spin, angular momentum addition, Wigner-Eckart theorem; scattering theory including partial wave analysis, born approximation, and formal scattering theory; identical particles, introduction to second quantization, and structure of complex atoms. Prerequisite: Physics 5301.

**PHYSICS 6311 Statistical Mechanics** (LEC 3.0)

A study of statistical ensembles; Maxwell-Boltzmann, FermiDirac and Einstein-Bose distribution laws, application to some simple physical systems. Prerequisites: Physics 4311, Physics 5301.

**PHYSICS 6323 Quantum Statistical Mechanics** (LEC 3.0)

Techniques for calculation of the partition function with examples drawn from interacting Fermi gas, interacting Bose gas, superconductors, and similar sources. Prerequisites: Physics 6311 and 6301.

**PHYSICS 6333 Condensed Matter Physics** (LEC 3.0)

A course in the physics of hard and soft matter including solids, liquids, and complex materials. Topics: atomic structure, mechanical properties, phonons, electronic structure, energy band theory, electronic correlations, transport properties, magnetism, superconductivity. Prerequisite: Physics 5301.

**PHYSICS 6353 Atomic And Molecular Structure** (LEC 3.0)

Applications of quantum mechanics to the structure of atoms and molecules; perturbation and variational calculations, self-consistent field, multiplets, angular momenta, Thomas-Fermi model, diatomic molecules, spectral intensities. Prerequisite: Physics 5301.

**PHYSICS 6363 Atomic Collisions** (LEC 3.0)

Basic quantum mechanical concepts involved in atomic scattering theory. Topics include the Born approximation elastic collisions, and inelastic collisions. Other specific topics will be chosen from the general areas of electron, ion, and atom collisions with atoms and molecules. Prerequisite: Physics 6353 or 6301.

**PHYSICS 6403 Mathematical Physics I** (LEC 3.0)

Vector spaces, generalized coordinate transformations, vector analysis, tensors, partial differential equations in physics and boundary value problems, orthogonal functions and solutions to ordinary differential equations, hypergeometric, confluent hypergeometric, Legendre, Laguerre, and Bessel functions, Hermite polynomials, Green's functions in one dimension. (Co-listed with Math 6802).

**PHYSICS 6413 Mathematical Physics II** (LEC 3.0)

Green's functions in three dimensions, integral equations, complex variable theory and contour integration, group theory with applications to quantum mechanics, solid state and molecular physics. Prerequisite: Math 6802 or Physics 6403. (Co-listed with Math 6803).

## Psychology

The psychological science department offers a master of science in industrial-organizational psychology (I-O). Our M.S. in I-O psychology degree provides a strong foundation in scientific methods, management of human resources, and applying strategies and training techniques to make organizations more effective. With predicted growth of 53 percent for I-O psychologists between 2012 and 2022, this career field is in high demand (*Occupational Outlook Handbook*, U.S. Bureau of Labor Statistics). Requirements for the program are listed on our website, <https://psych.mst.edu/academic-programs/graduate/>. The M.S. program is offered on campus and via distance education. Additional information about our distance education program can be found at the distance and continuing education website, <http://dce.mst.edu/credit/degrees/iopsychology/>.

# Master of Science in Industrial-Organizational Psychology

## Admission Requirements

Students interested in the M.S. in I-O psychology program should review the admissions requirements listed on our website (<https://psych.mst.edu/academic-programs/graduate/admission-requirements/>).

## Program Requirements

The M.S. in industrial-organizational psychology requires 40 credit hours which includes a thesis or non-thesis option. Students will complete 24 credit hours of core courses, 10 hours of methods courses, and either 6 hours of elective credits or 6 hours of thesis credits. Applied internship experiences are suggested, but not required as part of the program. The program will take at least 2 years to complete and classes are offered both on-campus and via distance.

### Core Courses (24 hours)

PSYCH 5020	Introduction to Industrial-Organizational Psychology
PSYCH 5601	Small Group Dynamics
PSYCH 5602	Organizational Development
PSYCH 5700	Job Analysis and Performance Management
PSYCH 6610	Leadership, Motivation, and Culture
PSYCH 6702	Personnel Selection
PSYCH 6602	Employee Affect and Behavior
PSYCH 6700	Training and Development

### Methods Courses (10 hours)

PSYCH 5201	Psychometrics
PSYCH 5210	Advanced Research Methods
PSYCH 5012	Ethics and Professional Responsibilities
PSYCH 5202	Applied Psychological Data Analysis

### Electives from list below or Thesis (6 hours)

PSYCH 5710	Advanced Human Factors
PSYCH 5600	Advanced Social Psychology
PSYCH 5001.001	
PSYCH 5001.002	

Students completing a thesis would need to complete the following in place of electives:

PSYCH 6099	Research
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## Applied Workplace Psychology

The applied workplace psychology graduate certificate is designed to serve as a recruitment tool for the industrial-organizational psychology MS program. This program will offer students a set of foundational courses in industrial and organizational psychology. Students who pass all four courses with a grade of B or better in each course can gain entry to the I-O psychology MS program with the other application requirements being waived. The included courses cover an introductory seminar course, an advanced research methods course, a course on job analysis and performance appraisal and a small group dynamics course which will examine groups and teams in organizations.

All four courses included in the applied workplace psychology certificate curriculum will be offered once per year. All of these courses are available both on-campus as well as via distance.

### Fall Courses:

PSYCH 5020	Introduction to Industrial-Organizational Psychology	3
PSYCH 5210	Advanced Research Methods	3

### Spring Courses:

PSYCH 5601	Small Group Dynamics	3
PSYCH 5700	Job Analysis and Performance Management	3

Admissions requirements for the applied workplace psychology certificate are available at <https://psych.mst.edu/academic-programs/graduate/admission-requirements/>

Students admitted to the applied workplace psychology certificate program will have non-degree graduate status, however, they will earn graduate credit for the course they complete. If the student completes the four-course sequence with a grade of B or better in each of the courses taken, they, upon application, will be admitted to the M.S. degree program in industrial organizational psychology. The certificate credits taken by the students admitted to the M.S. degree program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to begin the courses in the applied workplace psychology certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

## Statistical Methods in Psychology

This certificate program is designed to provide formalized education in the area of psychometrics. Psychometrics is the field of study concerned with the theory and technique of psychological measurement and includes the measurement of knowledge, abilities, attitudes, and personality traits. The field is primarily concerned with the study of differences between individuals and involves two major research tasks: (1) the construction of instruments and procedures for measurement; and (2) the development and refinement of theoretical approaches to measurement. After being admitted to the program, a student must take two courses from a group of three and an additional two courses from a second group of three.

The following two psychology courses will be required:

PSYCH 5201	Psychometrics
PSYCH 5202	Applied Psychological Data Analysis

And an additional two statistics courses chosen from these four:

STAT 5346	Regression Analysis
STAT 5353	Statistical Data Analysis
STAT 5643	Probability And Statistics
STAT 6344	Design And Analysis Of Experiments

Admissions requirements for the statistical methods in psychology certificate are available at <https://psych.mst.edu/academic-programs/graduate/admission-requirements/>

Students admitted to the certificate program will have a non-matriculated status as a graduate student. If they complete each of the four courses with a grade of B or better, they may be admitted to the Missouri S&T master's degree program in industrial-organizational psychology or mathematics and statistics if they apply and meet the program requirements. Students who do not have all of the prerequisite courses necessary to take a course in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

**Denise Baker**, Assistant Professor  
PHD Arizona State University

**Amy Belfi**, Assistant Professor  
PHD Univeristy of Iowa

**Devin Burns**, Assistant Professor  
PHD Indiana University

**Jessica L. Cundiff**, Assistant Professor  
PHD Pennsylvania State University

**Amber M Henslee**, Associate Professor  
PHD Auburn University Main Campus

**Merilee A. Krueger**, Teaching Professor  
MA University of Nebraska-Omaha

**Clair Kueny**, Assistant Professor  
PHD Saint Louis University

**Frances H Montgomery**, Emeritus Professor  
PHD Florida State University

**Susan L Murray**, Professor and Chair<sup>1</sup>  
PHD Texas A&M University

**Daniel Shank**, Assistant Professor  
PHD University of Georgia

**Ting Shen**, Assistant Professor  
PHD Michigan State University

**Nancy J Stone**, Professor  
PHD Texas Tech University

**PSYCH 5000 Special Problems** (IND 0.0-6.0)  
Problems or readings on specific subjects or projects in the department.  
Consent of instructor required.

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**PSYCH 5001 Special Topics** (LEC 0.0-6.0)  
This course is designed to give the department an opportunity to test a  
new graduate level course. Variable title.

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**PSYCH 5010 Seminar for Industrial / Organizational Psychology** (RSD 3.0)  
A seminar course for general overviews of the most recent research in  
Industrial-Organizational Psychology. Prerequisite: Graduate standing.

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**PSYCH 5012 Ethics and Professional Responsibilities** (LEC 1.0)  
Case studies examining the ethical practice of psychology in  
organizations will be discussed. This will include covering both the legal  
and ethical standards surrounding the consulting and practice of I-O  
psychology and personnel management in organizations. Prerequisite:  
Graduate standing.

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**PSYCH 5020 Introduction to Industrial-Organizational Psychology** (LEC 3.0)  
Review of the most recent theoretical and applied research in advanced  
personnel and organizational psychology. Topics will include personnel  
selection, training and performance appraisal, job attitudes, motivation,  
work groups and teams, leadership, organizational culture, and  
organizational development. Prerequisites: Graduate Standing.

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**PSYCH 5040 Oral Examination** (IND 0.0)  
(Variable) After completion of all other program requirements, oral  
examinations for on-campus M.S./PH.D students may be processed  
during intersession. Off-campus M.S. students must be enrolled in oral  
examination and must have paid an oral examination fee at the time of  
the defense/comprehensive examination (oral/written). All other students  
must enroll for credit commensurate with uses made of facilities and/or  
faculties. In no case shall this be for less than three (3) semester hours  
for resident students.

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**PSYCH 5200 Theories and Practice of Psychological Measurement** (LEC 3.0)  
An overview of psychological tests and batteries used in a variety of  
disciplines. An emphasis is placed on the proper development and use  
of these tests and test batteries. Tests examined will include tests of  
intelligence, aptitude, personality, and psychopathology. Prerequisite:  
Psych 4200 or graduate standing.

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**PSYCH 5201 Psychometrics** (LEC 3.0)  
An examination of statistical methods used to develop and refine  
measures of human performance, aptitudes, and personality. Topics  
include reliability and validity, data reduction, measuring inter-  
relationships among variables (e.g., factor analysis, multiple regression),  
and testing group differences. Prerequisite: Psych 5202.

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**PSYCH 5202 Applied Psychological Data Analysis** (LEC 3.0)  
This course will focus on those statistical methods most useful for  
advanced research in psychology. We will learn to use R, a powerful,  
open-source statistical programming platform, and work through  
examples with psychological data sets including such techniques as  
correlation, ANOVAs, regression, and chi-squared. Prerequisite: Graduate  
standing.

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**PSYCH 5210 Advanced Research Methods** (LEC 3.0)  
Research methods and techniques, with an emphasis on conducting  
psychological research in organizational settings. Topics discussed  
include: ethics, reliability and validity in measurement and application,  
proper uses of experimental, quasi-experimental, and survey  
methodologies, as well as advanced methodologies IRT, SEM, HLM, and  
Meta-Analyses. Prerequisite: Graduate standing.

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**PSYCH 5600 Advanced Social Psychology** (LEC 3.0)  
An advanced study of the behavior of individuals in interaction within  
groups. Consideration will also be given to the experimental literature  
dealing with the formal properties of groups, conformity and deviation,  
intergroup relations, and attitude formation and attitude change.  
Prerequisite: Psych 4600 or graduate standing.

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**PSYCH 5601 Small Group Dynamics** (LEC 3.0)  
This course covers group perception, identification, leadership, structure,  
conflict, cohesion, commitment, performance, norms, roles, influence,  
and decisions, and groups' relations, networks, and work teams. Students  
consider both theory and applications to their lives and organizations  
through observational, research, team and applied assignments.  
Prerequisite: Psych 4601 or graduate standing.

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**PSYCH 5602 Organizational Development** (LEC 3.0)

Examination of the field of organizational development theories and interventions. An emphasis is placed on research methods and application of practices related to individual processes, group processes, and organizational structures and functions that impact change and development strategies and interventions. Prerequisite: Psych 4602 or graduate standing.

**PSYCH 5603 Advanced Social Influence** (LEC 3.0)

An in-depth review of the principles and procedures that affect the process of social influence, with consideration given to attitudinal, compliance inducing, and perceptual influences. Students will consider the theoretical implications and practical applications of topics in social influence in the form of independent reading, research proposals and/or projects, and observational assignments. Prerequisite: Psych 4603 or graduate standing.

**PSYCH 5700 Job Analysis and Performance Management** (LEC 3.0)

A focus on the scientific measurement of job performance. An in-depth discussion of the science and methods of appropriate job and task analysis will be discussed. Additionally, students will focus on current issues in performance management and appraisal including scientific findings related to both objective and subjective measures of performance. Prerequisite: Psych 4700 or graduate standing.

**PSYCH 5710 Advanced Human Factors** (LEC 3.0)

An in-depth review of the foundations of human factors, focusing on the interaction of people with various forms of technology in a variety of environments. Topics include research and evaluation methods, displays (e.g., visual, auditory), attention and information processing, decision making, motor skills, anthropometry, and biomechanics. (Co-listed with ENG MGT 5330).

**PSYCH 5720 Advanced Human-Computer Interaction** (LEC 3.0)

This course examines the psychological research and theories that contribute to the field of human-computer interaction. An emphasis will be placed on engaging in critical evaluation of research and applying theoretical knowledge to effectively use computers in organizations. Prerequisite: Psych 4720 or graduate standing.

**PSYCH 5730 Environmental Psychology: Research and Practice** (LEC 3.0)

An in-depth review of the theoretical perspectives in environmental psychology and the psychological effects of various environments. An emphasis is placed on the review and integration of the research to explain the psychological issues related to various environments as well as to understand ways to effectively design living, educational, work, and recreational environments. Prerequisite: Psych 4730 or graduate standing.

**PSYCH 6085 Internship** (IND 0.0-6.0)

Students will apply critical thinking skills and discipline specific knowledge in a work setting based on a project designed by the advisor and employee. Activities will vary depending on the student's background and the setting. Requires a major report. Prerequisites: Completed Core and Methods courses; instructor consent.

**PSYCH 6099 Research** (IND 0.0-6.0)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisites: Consent of instructor required.

**PSYCH 6602 Employee Affect and Behavior** (LEC 3.0)

Theory and research surrounding employee attitudes, emotions, and behaviors with an emphasis on antecedents and outcomes of: job satisfaction, engagement, organizational justice, trait and state positive and negative affect, organizational citizenship, counterproductive work, and proactive behaviors and the Implications for both employees and organizations. Prerequisite: Psych 5020.

**PSYCH 6610 Leadership, Motivation, and Culture** (LEC 3.0)

Examination of research related to leadership, motivation, and the impact of organizational culture on organizational performance will be discussed. The course will focus on the application of psychological theories to enhance organizational functioning and to promote positive workplace behaviors. Prerequisite: Psych 5020.

**PSYCH 6611 Leadership for Engineers** (LEC 3.0)

Provides engineers with a background in leadership concepts and principles; enables students to develop practical skills in leading and managing through multiple personal assessment. Topics include leadership styles, managing commitments, conflict resolution, change management, emotional intelligence, team dynamics and business ethics. Prerequisite: Eng Mgt 5110 or Psych 4602.

**PSYCH 6700 Training and Development** (LEC 3.0)

Psychological theories of learning will be covered. Students will learn how evaluate training needs in an organization as well as how to subsequently develop, implement, and validate a training program in an organizational context. Prerequisite: Psych 5700.

**PSYCH 6702 Personnel Selection** (LEC 3.0)

Current trends and methods in personnel recruitment and selection including classification, and promotion will be examined. An emphasis will be placed on legal and methodological considerations that can impact proper testing and assessment procedures. Cognitive abilities, personality, physical abilities, and other non-cognitive assessments will be discussed. Prerequisite: Psych 5700.

## Systems Engineering

Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems by defining customer needs and required functionality early in the development cycle. Systems engineers are responsible for the design and management of complex systems guided by systems requirements. There is a growing need for engineers who are concerned with the whole system and can take an interdisciplinary and top down approach. Systems engineers need to be problem definers, not just problem solvers, and be involved with a system through its life cycle, from development through production, deployment, training support, operation, and disposal.

Graduate programs leading to the M.S. and Ph.D. degrees are offered in systems engineering. The graduate program builds on sound engineering undergraduate education, experience, and maintains engineering specialization diversity in its graduates.

Systems engineering research is supported by interdisciplinary research and collaboration. Research areas include: model based engineering, systems architecting, modeling and simulation, complex adaptive systems, computational intelligence, human system integration and infrastructure systems. The systems engineering graduate program, with over 600 graduates since 2000, contributes to the research challenges of systems engineering imposed by today's complex, adaptive, distributed, cooperative and dynamically changing engineering systems. As one of the leading systems engineering programs in the nation, Missouri S&T is the only university in the world to have four INCOSE (International Council on Systems Engineering) Stevens Doctoral Award recipients. Systems engineering faculty members are active leaders in systems engineering and architecting research, conferences and other professional activities and associations.

## Requirements for Completion

Students following their approved program of study will be assured of graduation upon maintenance of good academic standing. A minimum of 30 hours of course work (non-thesis) or 36 hours of course work (thesis) from the areas listed below must be completed with a cumulative grade point average of 3.00 (on a 4.00 scale) and a "C" grade or better in each course. Accumulation of more than 10 hours of "C" or "F" results in dismissal from the program. A maximum of nine hours of course work for M.S. degrees may be transferred from universities outside the University of Missouri System. Such credits for transfer must have been registered as graduate courses when they were taken. All courses applied to the degree require prior written advisor approval recorded on the study plan in the student's file. It is the responsibility of each student to apply for graduation with the Missouri S&T registrar's office during his or her last semester. Assistance on this final step can be provided by the engineering management and systems engineering department.

## Departmental Laboratories

The department has several "hands on" laboratories that have both a research and teaching focus. Each of our labs is directed by faculty members that work closely with students to enhance their learning experience. The description below gives a brief introduction that will help you understand the purpose of each lab.

### Smart Engineering Systems Lab (SESL)

The department established the Smart Engineering Systems Lab (SESL) to develop approaches in building complex systems that can adapt in the environments in which they operate. The term "smart" in the context indicates physical systems that can interact with their environment and adapt to changes both in space and time by their ability to manipulate the environment through self-awareness and perceived models of the world based on both quantitative and qualitative information. The emerging fields of cyber physical systems, deep neural networks, fuzzy logic, evolutionary programming, and complex adaptive systems provide essential tools for designing such systems.

The focus of the SESL is in developing smart engineering architectures that integrate and/or enhance the current and future technologies necessary for developing smart engineering systems while illustrating the real life applications of these architectures. The smart engineering systems design and operations cut across a diversity of disciplines, namely manufacturing, electrical, computer, and mechanical, biomedical, civil and other related fields such as applied mathematics, cognitive sciences, biology and medicine. Current research is on developing new models and tools for building complex systems architectures that are intelligent, modular, and adaptive.

### Design Engineering Center (DEC)

The center is one of the outreach arms of the engineering management and systems engineering department. The focus is on research and service activities in support of the educational goals of the department through externally funded projects. Current areas of research include total quality management, concurrent engineering, Taguchi Methods®, quality engineering, the product development process, and design optimization.

### Laboratory for Investment and Financial Engineering

The goal of the Laboratory for Investment and Financial Engineering is to develop techniques and computational tools for increasing investment and capital return while managing and reducing financial risk. This involves research into stocks and financial derivatives (options, futures, forwards, and swaps), financial risk and uncertainty, financial forecasting, market efficiency and behavioral finance, fundamental and technical analysis, equity valuation, real options, and engineering economics. In cooperation with the Smart Engineering Systems Lab, research in the lab may also involve the use of smart and intelligent systems, such as neural networks, fuzzy logic, genetic and evolutionary algorithms, expert systems, intelligent agents, artificial life, chaos and fractals, and dynamic and complex systems. Data mining, principal component analysis and various other forms of applied statistics are also used. Members of the lab have access to financial data and various financial modeling software packages.

### The Virtual and Augmented Reality Systems Engineering Lab (VASEL)

The Virtual and Augmented Reality Systems Engineering Lab (VASEL) has been established to complement ongoing and future research work within the department, the S&T campus and across the UM system. The research conducted in this lab will address current and future challenges faced at the boundaries and interfaces of science, technology and engineering research that are essential for the next level of scientific advances to address societal needs. These challenges are found at the nexus of various domains and require experts from all backgrounds of science and engineering to facilitate research leading to the emergence of new disciplines and the generation of knowledge, particularly in the areas of complex systems design and development.

The focus of the VASEL is the research and development of techniques and platforms that are essential to understanding the complementary and competitive teaming of humans with natural and engineered systems. This includes design and evaluation of human response to extreme events such as earthquakes and floods which informs our understanding of developing protocols to address these natural events. Research involving human response to manufactured events such as fires, shootings and even cyber-attacks similarly will lead to engineered strategies facilitated by the virtual environments used as experimental platforms.

## Additional Information

For additional information you can call our main department phone at 573-341-4572 or you can visit our web page at <http://emse.mst.edu/>.

## Master of Science Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: Regular status: 3.0 cumulative
- Graduate Record Exam (GRE): All students must submit current GRE scores. Students successfully completing one of the department's graduate certificates with a grade of B or better in all the certificate courses can be admitted without the GRE.
- Regular status:  $V+Q \geq 1100$ ,  $A \geq 4.0$  (former scoring) or  $V \geq 155$ ,  $Q \geq 148$ ,  $A \geq 4.0$
- Condition: Student must earn B or better in each of first four graduate (5000 or 6000 level) classes after conditional admission.
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.
- Regular status: 580/237/90
- Statement of Purpose: All applicants must submit a statement of purpose.
- Financial Support: Students in conditional status are not eligible for financial support from the department.
- Three reference letters

The M.S. degree program is offered on the Rolla campus and several locations including the Missouri S&T Global - St. Louis, and by distance education throughout the United States and selected international locations. Distance course lectures are archived upon completion of the lecture and all lectures are available to students through streaming video during the semester for review. These courses can be reached from anywhere at any time. It is feasible to obtain a Missouri S&T non-thesis M.S. degree regardless of your location.

The M.S. non-thesis program requires completion of at least 10 three-credit hour courses approved by the academic advisor. The M.S. with thesis option requires 36 credit hours including the thesis. All students are required to take the following:

### CORE Courses

SYS ENG 5101	System Engineering and Analysis	3
SYS ENG 6102	Information Based Design	3
SYS ENG 6103	Systems Life Cycle Costing	3
SYS ENG 6104	Systems Architecting	3
SYS ENG 6196	Systems Engineering Capstone	3
SYS ENG 6542	Model Based Systems Engineering	3

### Specialization Courses

Specialization courses provides students with the ability to address his/her technology needs in the context of the overall Systems Engineering program. These graduate courses can be selected from engineering or the physical science department as long as they are approved by the program director.

One of the graduate certificates may be substituted for a specialization track with the permission of the program director.

## Doctor of Philosophy Admission Standards

- B.S. in engineering, or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics (I, II) or Chemistry, Engineering Economy
- GPA: M.S. GPA = 3.5
- Graduate Record Exam (GRE): All students must submit current GRE scores.  $V+Q \geq 1100$ ,  $A \geq 4.0$  (former scoring) or  $V \geq 155$ ,  $Q \geq 148$ ,  $A \geq 4.0$
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study.
- Regular status: 580/237/92 (TOEFL)
- Statement of Purpose: All applicants must submit a statement of purpose.
- Three reference letters

A candidate for the Ph.D. in systems engineering must complete the equivalent of at least three years of full time work beyond the bachelor's degree. The content of all Ph.D. programs are individually structured by the student in consultation with and approved by the student's advisory committee. All requirements for the degree must normally be completed within an eight year period. At appropriate points in their program, Ph.D. students must pass both a Qualifying Exam and Comprehensive Exam. Off-campus students are expected to complete all requirements listed in the Missouri S&T Graduate Catalog under the section entitled Doctor of Philosophy Degree and follow all procedures listed under the Procedures for Ph.D. Candidates.

The total credit requirements for graduation are a minimum of 54 credit hours after the successful completion of M.S. degree in systems engineering. Actual courses taken will be determined by the candidate's committee and his/her plan of study. The student is expected to complete all requirements.

### For Off-Campus Students

The qualifying exam must be taken on campus within the first 5 semesters of enrollment; the student will have at minimum one virtual conference per month with his/her research advisor; the student is expected to meet with the Ph.D. committee on a regular basis with at least two meetings per semester; the Ph.D. comprehensive exam must be taken on campus; the student has the option of conducting research that is beneficial to the student's professional work; and the defense of dissertation must take place on campus.

### Major Requirements

After B.S. degree in Engineering

<b>Core Curriculum</b>	<b>24</b>	
SYS ENG 6412	Mathematical Programming	3
SYS ENG 6110	Optimization under Uncertainty	3
SYS ENG 6101	Advanced Research Methodology in Engineering Management	3
SYS ENG 6104	Systems Architecting	3
SYS ENG 5101	System Engineering and Analysis	3
SYS ENG 6542	Model Based Systems Engineering	3
SYS ENG 6321	Modeling Complex Systems	3
SYS ENG 6239	Smart Engineering System Design	3
<b>Research</b>	<b>30</b>	
SYS ENG 6099	Research	1-15
<b>Electives</b>	<b>36</b>	

Systems Eng Process Tools, Optimization &amp; Statics - 12 credit hours

Research Specialization Areas - 24 credit hours

## Requirements for Thesis

Students will conduct original research demonstrated by journal or referred proceedings, publication under the supervision of a doctoral advisor, and communicate their findings, write a dissertation on research conducted, and provide satisfactory defense of their dissertation in a final oral examination. Students will be required to sign up for one hour of SYS ENG 6099 under their research advisor. Students are required to publish their work in approved journals and referred proceedings. A minimum of three articles is expected.

## Qualifying Exam

The objective of the systems engineering Ph.D. qualifying exam is to test the knowledge and understanding of the graduate student on systems engineering fundamentals and student's research capability.

It is expected that the graduate student has a clear understanding of the research issues in the student's area of interest, its implications in industrial applications primarily in the industrial domain the student is working, possible impact of successful research contributions to systems engineering research and literature. For more information, contact the department graduate staff.

## Comprehensive Exam

The student's advisory committee will administer the comprehensive examination after the student has completed seventy-five percent of the coursework for the Ph.D. program and one published refereed conference proceeding or journal paper. The examination is written and oral. Upon successful completion of the written examination, the student will be orally examined by the advisory committee.

## Dissertation

The dissertation, embodying the results of an original investigation, must be written upon a subject mutually agreed upon between the student and the advisor.

## Research Areas

Cyber Physical Systems, Modeling and Simulation, Model Based Systems Engineering, System of Systems Architecting, Complex Adaptive Systems, Human System Integration, Infrastructure Systems.

## Graduate Certificate Programs

This program is designed to appeal to working professionals. Certificate courses taken for graduate credit can be counted in the M.S. degree once accepted into the M.S. degree. If the four-course sequence is completed with a grade of "B" or better in each of the courses taken, they can apply to be admitted to the M.S. systems engineering. The certificate program may be followed by six to eight additional 3 credit hour courses to complete the M.S. degree. The certificate program is open to all persons holding a B.S., M.S., or Ph.D. degree in engineering or a physical science and who have a minimum of 12-months of professional employment experience or are currently accepted into a graduate degree program at Missouri S&T.

## Admission Standards

- B.S. in engineering or a physical science
- Undergraduate courses: Calculus Series (I, II, III), Differential Equations, Statistics, Physics or Chemistry, Engineering Economy

- GPA: Regular status: 2.75 cumulative
- TOEFL: All international applicants must submit a current TOEFL score, regardless of prior academic experience or place of study
- Regular status: 580/237/90

Once admitted to the program, the student must take the four designated courses as given below. In order to receive a graduate certificate, the student must have an average cumulative grade point of 3.0 or better in the certificate courses.

## Computational Intelligence Certificate

Recent advances in information technology and the increased level of interconnectivity that society has achieved through Internet and broadband communication technology created systems that are very much different. The world is facing an increasing level of systems integration leading towards systems of systems (SoS) that adapt to changing environmental conditions. The number of connections between components, the diversity of the components and the way the components are organized can lead to different emergent system behavior. Computational Intelligence tools are an integral part of these systems in enabling adaptive capability in their design and operation.

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use and development of computational intelligence algorithms based on evolutionary computation, neural networks, fuzzy logic, and complex systems theory. Engineers can also learn how to integrate common sense reasoning with computational intelligence elective courses such as data mining and knowledge discovery.

### Core Courses

COMP ENG 5310/ ELEC ENG 5310/ SYS ENG 5211	Computational Intelligence
Select one of the following:	
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications
COMP SCI 5400	Introduction To Artificial Intelligence
COMP SCI 5401	Evolutionary Computing
Select two of the following not taken as a core course:	
SYS ENG 5212/ ELEC ENG 5370	Introduction to Neural Networks and Applications
ELEC ENG 5320	Neural Networks Control and Applications
COMP SCI 5400	Introduction To Artificial Intelligence
COMP SCI 5401	Evolutionary Computing
COMP SCI 6400	Advanced Topics In Artificial Intelligence
COMP SCI 6401	Advanced Evolutionary Computing
SYS ENG 6213	Deep Learning and Advanced Neural Networks
SYS ENG 6214/ COMP ENG 6330/ ELEC ENG 6340/ STAT 6239	Clustering Algorithms
SYS ENG 6215/ COMP ENG 6320/ ELEC ENG 6360	Adaptive Dynamic Programming
SYS ENG 6216/ COMP ENG 6302/ COMP SCI 6402	Advanced Topics in Data Mining
COMP ENG 6310/ ENG MGT 6410/ COMP SCI 6202/ MECH ENG 6447/ AERO ENG 6447	Markov Decision Processes

## Model Based Systems Engineering Certificate

Recent advances in technology demands and the increased level of interconnectivity achieved through Internet and broadband communication technology is leading to systems that are increasingly complex. To manage this complexity, computational modeling and data resources have become nearly ubiquitous in systems engineering, driving the profession from a document-centric paradigm to a model-centric one. Model based systems engineering provides the means to construct models that capture system structure, behavior, and requirements and maintain consistency of these models automatically between collaborating engineers. These models can then be used in tandem with engineering and mathematics tools to quickly gain insight into the overall system performance over the entire lifecycle before a system component is ever made.

This graduate certificate program provides practicing engineers the opportunity to develop the necessary skills in the use of current modeling techniques to develop and simulate complex, multi-disciplinary engineering systems. In addition, engineers will learn methods to automate data acquisition for system development, establish rules for usability of model resources, and acquire necessary skills for simulating the designed systems.

SYS ENG 6110	Optimization under Uncertainty
SYS ENG 6239	Smart Engineering System Design
SYS ENG 6412	Mathematical Programming
SYS ENG 6542	Model Based Systems Engineering

## Cyber Physical Systems Graduate Certificate

Cyber Physical Systems with different levels of implementation that entail complex logic with many levels of reasoning in intricate arrangement, organized by web of connections and demonstrating self-driven adaptability are emerging. They will impact manufacturing industry, defense, healthcare, energy, transportation, emergency response, agriculture and society overall. The graduate certificate in Cyber Physical systems is a joint effort between computer engineering and systems engineering to provide practicing engineers with the necessary skills to develop and design the operation of complex adaptive systems. These four courses count towards a M.S. degree in systems engineering or computer engineering and they address the intersection between computer engineering, systems engineering, and architecting. The requirements are the successful completion of two core courses and two elective courses from the list below. A grade of "B" or better is required in each course before the student is eligible for the master of science program.

### Core Course:

SYS ENG 6321/ COMP ENG 6410	Modeling Complex Systems
COMP ENG 5410	Introduction to Computer Communication Networks

### Elective Courses (Select two courses):

COMP ENG 5420	Introduction to Network Security
COMP ENG 5430/ SYS ENG 5323	Wireless Networks
COMP ENG 5510	Fault-Tolerant Digital Systems
SYS ENG 6322/ COMP ENG 6510	Resilient Networks
COMP ENG 6420/ SYS ENG 6324	Wireless Ad hoc and Sensor Networks
COMP ENG 6430	High Speed Networks
COMP ENG 6440/ COMP SCI 6602	Network Performance Analysis

COMP SCI 6600	Formal Methods in Computer Security
COMP SCI 6604	Mobile And Sensor Data Management

## Systems Engineering Graduate Certificate

The graduate certificate in systems engineering is designed to provide graduate engineers with the advanced knowledge and skills necessary for the conception and implementation of complex systems. The emphasis is on the processes by which complex systems are conceived, planned, designed, built, tested, and certified. The systems engineering experience can be applied to defense, space, aircraft, communications, navigation, sensor, computer software, computer hardware, transportation, and other aerospace and commercial activities.

SYS ENG 5101	System Engineering and Analysis
SYS ENG 6102	Information Based Design
SYS ENG 6103	Systems Life Cycle Costing
SYS ENG 6104	Systems Architecting

Upon successful completion of the four courses as described above, students will be awarded certification. The student must complete the four courses with a grade of "B" or better in each course. Students may apply to the M.S. program with the completion of the certificate.

### Venkat Allada, Professor

PHD University of Cincinnati

Sustainable produce development, product platform design, mass customization, product innovation, lean manufacturing, intelligent manufacturing systems, process planning supply chain management, systems engineering process and design.

### Casey Canfield, Assistant Professor

PHD Carnegie Mellon University

Human Systems Integration, Human Factors, Automation, Energy Systems, Smart Cities, Organizational Behavior, Decision Science, Risk Analysis, Risk Communication, Data Visualization, Policy Analysis, Behavioral Interventions, Program Evaluation, Implementation Science, Stakeholder Engagement.

### K Chandrashekhara, Curators Distinguished Professor

PHD Virginia Polytechnic Institute

Structures and Composite Materials.

### Steven M. Corns, Associate Professor

PHD Iowa State University

Associate Chair of Graduate Studies. Computational Intelligence, Complex Systems, Bioinformatics, Infrastructure Systems Modeling, Autonomous Systems.

### Elizabeth Anne Fargher Cudney, Associate Professor

PHD Missouri S&T

Quality, Six Sigma, Robust Engineering, and Lean Enterprise.

### Cihan H Dagli, Professor

PHD University of Birmingham, UK

Systems Architecting and Engineering, Cyber Physical Systems, Machine Learning, Deep Learning, Computational Intelligence. INCOSE Fellow, IISE, IFPR Fellow.



**David Enke**, Professor  
 PHD University of Missouri-Rolla  
 Investments, Derivatives, Options and Futures, Financial Forecasting, Trading Strategies, Hedge Funds, Endowment Investing, Financial Risk Management, Engineering Economy, Computational Finance, Computational Intelligence, Neural Networks.

**Abhijit Gosavi**, Associate Professor  
 PHD University of South Florida  
 Lean manufacturing, supply chain management, revenue management, simulation-optimization.

**Katie Grantham**, Associate Professor  
 PHD University of Missouri-Rolla

**Sheryl Hodges**, Assistant Teaching Professor  
 DEng Louisiana Tech Univeristy  
 Program/Project Management, Financial Management, Organizational Management, Engineering/Construction.

**Benjamin Kwasa**, Assistant Professor  
 PHD Iowa State University  
 Organization Design in the Design of Complex Systems, Unmanned Aerial Systems Integration, Value-Driven Design, Multidisciplinary Design Optimization, Heuristic Optimization, Systems Design, Systems Engineering, Preference Formulation and Communication, Risk Simulation in Design and Modeling, Engineering Education, Meta-Modeling, Decision Analysis, Systems Requirements Development.

**Jinling Liu**, Assistant Professor  
 PHD The Pennsylvania State University  
 Artificial Intelligence, Biomedical Informatics, Precision Medicine, Big Data Analytics, Systems Biology, Immunology, Causal Inference, Multi-omics data.

**Suzanna K. Long**, Professor  
 PHD University of Missouri-Rolla  
 Critical Infrastructure Systems, Strategic Management, Sustainable Infrastructures, Management, Supply Chain and Transportation, Systems Management, Organizational Behavior, Sociotechnical Systems Analysis.

**Robert Marley**, Robert B. Koplal Professor  
 PHD Wichita State University  
 Human System Integration, Ergonomics.

**Ruwen Qin**, Associate Professor  
 PHD Pennsylvania State University  
 Real options, financial engineering, and manufacturing and service operations.

**Stephen A Raper**, Associate Professor  
 PHD University of Missouri-Rolla  
 Packaging engineering, operations, productivity, total quality management, packaging systems design, environmental aspects of packaging and statistical process control.

**Jagannathan Sarangapani**, Professor  
 PHD University of Texas-Arlington  
 Adaptive Control, Wireless Networks.

**Joan Barker Schuman**, Associate Teaching Professor  
 PHD University of Southern Mississippi  
 Project Management and Engineering Economics.

**David G Spurlock**, Associate Teaching Professor  
 PHD University of Illinois Urbana  
 General Management.

**Donald C Wunsch II**, Professor<sup>1</sup>  
 PHD University of Washington  
 Adaptive critic designs, neural networks, fuzzy systems, surety, nonlinear adaptive control, intelligent agents, applications.

**SYS ENG 5000 Special Problems** (IND 1.0-6.0)  
 Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**SYS ENG 5001 Special Topics** (LAB 0.0 and LEC 0.0)  
 This course is designed to give the department an opportunity to test a new course. Variable title.

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**SYS ENG 5040 Oral Examination** (IND 0.0)  
 After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**SYS ENG 5099 Research** (IND 1.0-15)  
 Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

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**SYS ENG 5101 System Engineering and Analysis** (LEC 3.0)  
 The concepts of Systems Engineering are introduced through a project. Students work in virtual teams. The topics covered are architecture development, basic system architectural design techniques, functional decomposition, design and technical review objectives, and initial specifications. Prerequisite: Graduate Standing.

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**SYS ENG 5105 Project Management** (LEC 3.0)  
 Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisites: Graduate standing. (Co-listed with Eng Mgt 5320).

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**SYS ENG 5211 Computational Intelligence** (LEC 3.0)  
 Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Elec Eng 5810 and Comp Eng 5310).

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**SYS ENG 5212 Introduction to Neural Networks and Applications** (LEC 3.0)

The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Elec Eng 5370).

**SYS ENG 5323 Wireless Networks** (LAB 1.0 and LEC 2.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Comp Eng 5430 and Elec Eng 5430).

**SYS ENG 6000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**SYS ENG 6001 Special Topics** (LEC 1.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**SYS ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**SYS ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**SYS ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from campus must continue to enroll for at least one credit hour each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**SYS ENG 6099 Research** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

**SYS ENG 6101 Advanced Research Methodology in Engineering Management** (LEC 3.0)

An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing. (Co-list with Eng Mgt 6101).

**SYS ENG 6102 Information Based Design** (LEC 3.0)

This course is an introduction to the use of common data analytical methods and analysis for the purpose of decision making during the design phase of engineering system development. Through the introduction to such analytical methodologies, the systems engineering tool belt is made more effective as it is the foundation to decision analysis. Prerequisites: Graduate Standing.

**SYS ENG 6103 Systems Life Cycle Costing** (LEC 3.0)

Methods of economic evaluation for engineering projects involving complex systems. Economic impacts on choosing system alternatives, life cycle costing, economic decisions involving risk and uncertainty, and engineering cost estimation for projects in government, defense, and commercial industries. Prerequisites: Graduate Standing.

**SYS ENG 6104 Systems Architecting** (LEC 3.0)

Tools and concepts of architecting complex engineering systems. Ambiguity in Systems Architecting and Fuzzy Systems; Search as an Architecting Process; Architecting Heuristics; Systems Scoping and Attribute Selection; Assessing Architectures; Systems Aggregation, Partitioning; Systems Behavior Generation; System Science and Thinking, Cyber Physical Systems. Prerequisites: Graduate Standing.

**SYS ENG 6105 Complex Engineering Systems Project Management** (LEC 3.0)

The course topics include issues specific to distributed project management, team development, resource management, constraint planning, development of Integrated Master Schedule and Integrated Master Plan, monitoring technical performance, schedule, cost, and risk. Prerequisites: Graduate Standing.

**SYS ENG 6110 Optimization under Uncertainty** (LEC 3.0)

Optimization in the presence of model uncertainty or system stochasticity is discussed. The course covers fundamentals of stochastic programming, robust optimization, and dynamic programming. Prerequisite: Graduate standing. (Co-listed with ENG MGT 6415).

**SYS ENG 6167 Software Intensive Systems Architecting** (LEC 3.0)

Basic tools and concepts of architecting complex software intensive systems are introduced. The following topics are covered under four main sections; namely Architecting Process, Architecting Heuristics, Architecting Patterns and Frameworks, and Architecture Assessment. Prerequisite: Graduate Standing.

**SYS ENG 6196 Systems Engineering Capstone** (LEC 3.0)

The topics covered are Systems Engineering Management Plan (SEMP), Systems Engineering processes, process re-engineering, standards, and systems engineering case studies. Students will apply the skills and theory that they mastered in previous five core courses to the analysis of assigned cases. Prerequisites: Sys Eng 6105.

**SYS ENG 6213 Deep Learning and Advanced Neural Networks** (LEC 3.0)

Use of deep learning and advanced neural networks in the design of cyber physical complex adaptive systems. Machine learning basics, deep feed forward networks, regularization for deep learning, optimization for training deep models, convolutional networks, recurrent and recursive nets, practical, vision and natural language processing applications. Prerequisite: Graduate Standing.

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**SYS ENG 6214 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Comp Sci 6405 and Stat 6239).

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**SYS ENG 6215 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Mech Eng 6458 and Aero Eng 6458).

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**SYS ENG 6216 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 5001 Introduction to Data Mining. (Co-listed with Comp Sci 6402 and Comp Eng 6302).

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**SYS ENG 6217 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisites: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Eng Mgt 6410, and Comp Sci 6202).

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**SYS ENG 6239 Smart Engineering System Design** (LEC 3.0)

Covers the tools, techniques and methods used in developing Flexible Intelligent Learning Architectures for system of systems (SoS) and cyber physical systems (CPS) through evolutionary approach. Meta-architecture generation algorithms, SoS and CPS architecture evaluation methods, executable architectures, many meta-architecture objectives trade. Prerequisites: Graduate Standing.

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**SYS ENG 6321 Modeling Complex Systems** (LEC 3.0)

Engineering Systems of today are non-linear, distributed, global, and adaptive to their environment in both space and time, thereby creating emergent behaviors. This course covers the current modeling tools and techniques used in modeling and architecting these complex systems. Prerequisites: Graduate Standing. (Co-listed with COMP ENG 6410).

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**SYS ENG 6322 Resilient Networks** (LEC 3.0)

This course presents reliability and fault tolerance for network-centric systems, including models, metrics, and analysis techniques. This course also concentrates on security, including technical tools and methods for audit and assessment as well as management and policy issues. Prerequisites: Sys Eng 6410, Comp Eng 6410, or Comp Eng 5420. (Co-listed with COMP ENG 6510).

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**SYS ENG 6324 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Elec Eng 6430).

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**SYS ENG 6412 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Math 6665 and Eng Mgt 6412).

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**SYS ENG 6541 Distributed Systems Modeling** (LEC 3.0)

This course will discuss issues related to distributed systems architecting, modeling, analysis and representation, with specific focus on discrete-part manufacturing domain. Distributed modeling techniques and other model decomposition methods using simulation modeling and scalability issues will also be addressed.

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**SYS ENG 6542 Model Based Systems Engineering** (LEC 3.0)

Provides the student with understanding of the use of models to represent systems and validate system architectures. The student will gain proficiency in using a systems modeling language and shifting systems engineering from a document centric to a model centric paradigm. Prerequisites: Graduate Standing. (Co-listed with COMP SCI 6102).

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**SYS ENG 6612 Investment** (LEC 3.0)

An introduction to the theory and practice of investment, including financial markets and instruments, security trading, mutual funds, investment banking, interest rates, risk premiums, the capital asset pricing model, arbitrage pricing theory, market efficiency, bonds and the fixed income market, equity valuation, fundamental and technical analysis. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6212).

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**SYS ENG 6613 Financial Engineering** (LEC 3.0)

An introduction to financial engineering, with an emphasis on financial derivatives, including the future markets, the pricing of forwards and futures, forward rate agreements, interest and exchange rate futures, swaps, the options markets, option strategies, the binomial and Black-Scholes models for option valuation, the option Greeks, and volatility smiles. Prerequisites: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6213).

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**SYS ENG 6614 Financial Engineering II** (LEC 3.0)

This course introduces advanced topics in financial engineering, which includes introduction to Wiener processes, martingales and Ito's lemma; basic numerical methods for options pricing, exotic options; interest rate models; stochastic volatility models and jump-diffusion models; and value-at-risk. Prerequisite: Eng Mgt 6213/Sys Eng 6613. (Co-listed with Eng Mgt 6214).

**SYS ENG 6615 Financial Risk Management** (LEC 3.0)

Techniques and methods for managing financial risk, including portfolio theory, Monte Carlo methods, ARIMA, time series forecasting, Value-at-Risk, stress testing, extreme value theory, GARCH and volatility estimation, random variables and probability distributions, real options, decision trees, utility theory, statistical decision techniques, and game theory. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6215).

## Technical Communication

At the graduate level, three technical communication programs are offered in the department of English and technical communication: a master of science in technical communication, a graduate minor in technical communication, and a graduate certificate in technical communication.

The English and technical communication department offers a master's degree in technical communication (either online or traditional) for any student with a bachelor's degree in any discipline and a strong background in writing and technology. Because of the rapid changes in technology, particularly due to the effects of information systems, there is an immediate and growing need for highly trained professional communicators to design information. Employers are looking for communicators with sophisticated skills in the integration of visual communication tools with written and spoken communication.

Faculty involved in a variety of technical communication research programs teach and direct the program. Students will have opportunities to assist these faculty, both in research and teaching, as well as to work alongside faculty and graduate students in engineering and science. The technical communication faculty and students are active in the leading professional societies.

The program requires a minimum of 30 hours of graduate credit and includes both a thesis and non-thesis option.

## M.S. Degree Requirements

Ten courses totaling 30 credit hours are required for the M.S.:

All MS students must take TCH COM 6600: Foundations of Technical Communication.

The remaining courses should come from the following list and should be determined in consultation with the student's academic advisors. Students must take 3 TCH COM courses at the 6000 level.

TCH COM 5510	Technical Editing	3
TCH COM 5520	Help Authoring	3
TCH COM 5530	Usability Studies	3
TCH COM 5540	Advanced Layout and Design	3
TCH COM 5550	Advanced Proposal Writing	3
TCH COM 5560	Web-Based Communication	3
TCH COM 5610	History of Technical Communication	3

TCH COM 5620	Research Methods in Technical Communication	3
TCH COM 6001	Special Topics	0-6
TCH COM 6070	Teaching of Technical Communication	3
TCH COM 6410	Theoretical Approaches to Technical Communication	3
TCH COM 6420	Project Management in Technical Communication	3
TCH COM 6440	Advanced Theories of Visual Technical Communication	3
TCH COM 6450	Advanced International Technical Communication	3

Thesis Option: Students interested in pursuing a PhD in technical communication have the option of writing a supervised thesis as part of their coursework. If the student chooses to do a thesis, and the technical communication faculty give their approval to this plan, the student will take 6 hours of TCH COM 5099 (<http://catalog.mst.edu/search/?P=TCH%20COM%205099>) Research. Three of these hours may count toward the 30 hr total, but an additional 3 hrs will be required, bringing the total number of degree hours to 33. Completing TCH COM 5620: Research Methods before proposing a thesis is highly recommended.

## Technical Communication Graduate Minor

The technical communication program offers a graduate-level minor that is open to any graduate student. The minor is designed to strengthen the written, oral, and visual communication skills of students majoring in the sciences, engineering, management, information systems, or other fields. The minor will be particularly useful for those students who will pursue the "paper option" thesis or dissertation. The minor will also be beneficial for those students who will make oral or poster presentations at technical conferences, write journal articles, prepare research proposals, design technical web pages, or prepare technical marketing information.

The program requires a minimum of 12 hours of credit (excluding all courses taken for undergraduate credit). A minimum of 6 hours of 4000-level or above courses with the TCH COM designation is required. At least 6 additional hours of technical communication intensive courses are required. The additional courses may come from courses with the TCH COM designation, the list of approved technical communication intensive courses, and/or technical communication intensive courses from any academic discipline with the approval of the minor advisor and the English and technical communication department.

Students can elect to pursue this minor at any point during their graduate studies by submitting the Application for a Designated Graduate Minor form (available at <http://registrar.mst.edu/media/administrative/registrar/documents/gradminorapp.pdf>) to the English and technical communication department. Upon application, each student will be assigned a minor advisor who will work with the student to develop a proposed list of courses to fulfill the program requirements.

## Approved Technical Communication Intensive Courses

All TCH COM courses, 4000-level and above

BIO SCI 6313	Environmental Microbiology	3
BUS 4111	Business Negotiations	3
ENGLISH 2410	Theory Of Written Communication	3
ENGLISH 5571	Advanced Writing For Science & Engineering	3
GEO ENG 5092	International Engineering and Design	3
IS&T 6887	Research Methods in Business and IS&T	3
MATH 3109	Foundations Of Mathematics	3
MATH 5603	Methods of Applied Mathematics	3
MATH 5108	Linear Algebra II	3

MATH 5154	Mathematical Logic I	3
MS&E 6120	Thermodynamics and Phase Equilibria	3

The technical Communication Graduate Minor Advisory Committee will evaluate other courses, upon the request of students or faculty, for inclusion on the approved list or on a case-by-case basis for individual programs.

The graduate certificate in technical communication serves current Missouri S&T graduate students in any discipline; individuals who already have undergraduate or graduate degrees and are seeking to add value to their degrees; and current industry employees who need to hone their communication skills to remain competitive in the market and better serve their employers.

The certificate may be pursued either online or on campus.

The following 4 courses\* (totaling 12 credit hours) will be required for the certificate:

TCH COM 5510	Technical Editing
TCH COM 5530	Usability Studies
TCH COM 5550	Advanced Proposal Writing
TCH COM 5560	Web-Based Communication

These four courses are also required for the M.S. in technical communication and could be counted toward that degree if the certificate student later decided to go on for the M.S.

\* Course substitutions may be permitted by the department in some circumstances.

**Carleigh Davis**, Assistant Professor  
PHD East Carolina University

**Ed A. Malone**, Professor  
PHD Southern Illinois University Carbondale

**Kathryn Michele Northcut**, Professor  
PHD Texas Tech University

**Michael David Wright**, Associate Professor  
PHD Oklahoma State University Main

***TCH COM 5000 Special Problems*** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

***TCH COM 5001 Special Topics*** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

***TCH COM 5010 Seminar*** (RSD 0.0-6.0)

Discussion of current topics. Prerequisites: One semester of college composition or technical writing, or graduate standing.

***TCH COM 5040 Oral Examination*** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

***TCH COM 5099 Research*** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

***TCH COM 5510 Technical Editing*** (LEC 3.0)

The principles and practices of technical editing, including usability, audience analysis, contextual editing, the conventions of scientific and technical communication, and the role of the editor in document development and publication. Students will also learn standard practices of copy editing and the use of style guides. Prerequisites: One semester of college composition or technical writing, or graduate standing.

***TCH COM 5520 Help Authoring*** (LEC 3.0)

Students will acquire the technological and rhetorical skills necessary for creating effective online help systems, including context-sensitive help for computer applications. Prerequisites: One semester of college composition or technical writing, or graduate standing.

***TCH COM 5530 Usability Studies*** (LEC 3.0)

Students in this course will study and apply methods used by technical communicators to evaluate usability. Students will study methods used to evaluate human interaction with communication tools and how to make those products more suitable for human use. Prerequisites: One semester of college composition or technical writing, or graduate standing.

***TCH COM 5540 Advanced Layout and Design*** (LEC 3.0)

Advanced theory and practice of layout and design for print and electronic media. Prerequisite: English 2540 or TCH COM 2540, or graduate standing.

***TCH COM 5550 Advanced Proposal Writing*** (LEC 3.0)

Familiarizes graduate students with many aspects of writing proposals for various purposes in academic, professional, and public spheres. Offers opportunities to write documents to promote their academic, professional, or personal goals or those of their organization(s). Credit will not be given for both TCH COM 4550 and TCH COM 5550. Prerequisites: Graduate standing.

***TCH COM 5560 Web-Based Communication*** (LEC 3.0)

Covers such topics as advanced writing and editing for the web; the creation of rhetorically effective websites; the use of blogs, wikis, and other web genres to communicate technical information. Prerequisites: One semester of college composition or technical writing, or graduate standing.

**TCH COM 5610 History of Technical Communication** (LEC 3.0)

Introduction to the roles of the technical communicator and the technologies of communication from ancient cultures to the present. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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**TCH COM 5620 Research Methods in Technical Communication** (LEC 3.0)

Students learn essential research methods in technical communication, including audience analysis, interviewing techniques, working with subject matter experts, and experimental research design. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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**TCH COM 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**TCH COM 6070 Teaching of Technical Communication** (LEC 3.0)

Provides a theoretical and pedagogical foundation for teaching workshops and undergraduate courses in technical communication. Includes both traditional and electronic settings.

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**TCH COM 6410 Theoretical Approaches to Technical Communication** (LEC 3.0)

Examines representative theories and research in written, oral, and visual modes of technical communication. Includes such issues as ethics, document design, rhetorical methods, and people-machine communication.

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**TCH COM 6420 Project Management in Technical Communication** (LEC 3.0)

Study of and practice in directing projects related to such areas as multimedia, web sites, strategic planning, newsletters. Includes writing planning documents, selecting team members, synchronizing assignments, testing prototypes, and issuing a final report.

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**TCH COM 6440 Advanced Theories of Visual Technical Communication** (LEC 3.0)

An in-depth investigation and analysis of historical and contemporary visual theories and their impact on technical communication, including visual rhetoric, semiotics, and design and critical theories.

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**TCH COM 6450 Advanced International Technical Communication** (LEC 3.0)

Advanced study of international technical communication. Includes topics such as graphics, icons, symbols; user interface design; intercultural communication. Students may not earn credit for both TCH COM 4450 and TCH COM 6450.

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**TCH COM 6600 Foundations of Technical Communication** (LEC 3.0)

Introduction to themes and issues, methods, and genres that define technical communication.

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# COURSE INFORMATION

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## Course Numbers

This section has been prepared to give you a listing and description of the approved courses at the Missouri University of Science and Technology. Courses listed are those approved at the time this publication went to press. Changes are made at regular intervals. Electronic catalog descriptions, which are updated during the academic year, are available on the Web at: <http://catalog.mst.edu/> or on Joe'SS. This will enable you to keep abreast of new course additions. For current information on when courses are available, consult the campus schedule of classes available on the Registrar's Office website at <http://registrar.mst.edu>.

**1000-1999** Freshmen-level courses. May not be used as any part of a graduate degree program.

**2000-2999** Sophomore-level courses. May not be used as any part of a graduate degree program.

**3000-3999** Junior-level courses.

**4000-4999** Senior-level courses.

**5000-5999** Entry and mid-level graduate courses (undergraduate enrollment allowed).

**6000-6999** Advanced graduate courses. Undergraduate and post-baccalaureate students are not normally eligible to enroll in 6000-level courses.

## Course Information

The number in parentheses following the name of the course indicates the number of credit hours given for successfully completing the course. It also reflects the section type; for example, (LEC 3.0) designates a lecture course of three hours credit; (LAB 1.0) designates a laboratory course of one-hour credit, (RSD 2.0) designates a recitation, seminar, discussion of two hours credit, and (IND 0.0-15.0) designates independent study or research with variable hours. A lecture credit hour is usually the credit granted for satisfactorily passing a course of approximately 15 classroom hours. A laboratory course of one-hour credit would normally meet three classroom hours per week for 15 weeks.

Three credit hour courses normally meet 50 minutes three times per week, or 75 minutes twice a week, for 15 weeks. The time in class is the same in each case. If you have two classes in succession, there should be at least 10 minutes between classes. Classes meeting Monday-Wednesday-Friday will normally begin on the hour. Classes meeting Tuesday-Thursday will normally alternate between the hour and half hour, beginning at 8:00 a.m.

Students must have completed the stated prerequisite(s) for the course for admission to the course or obtain the 'Consent of the Instructor' of the course.

# COURSE LIST

## Aerospace Engineering (AERO ENG)

### **AERO ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

### **AERO ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Mech Eng 5001).

### **AERO ENG 5131 Intermediate Thermofluid Mechanics** (LEC 3.0)

Derivation of Navier-Stokes equations, analytical solutions of viscous flows; flow in pipes, flow networks; intermediate treatment of boundary layer theory; micro-fluidics and MEMS; introduction to numerical methods for solving fluid flows; and, preliminary treatise on turbulence. Prerequisite: Mech Eng 3131 or Aero Eng 3131. (Co-listed with Mech Eng 5131).

### **AERO ENG 5139 Computational Fluid Dynamics** (LEC 3.0)

Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Comp Sci 1570 or 1970 or 1971; one course in fluid mechanics. (Co-listed with Mech Eng 5139).

### **AERO ENG 5169 Introduction to Hypersonic Flow** (LEC 3.0)

A study of the basic principles of hypersonic flow. Inviscid and viscous hypersonic flow. Application of numerical methods. High temperature flow. Consideration of real gas and rarefied flow. Applications in aerodynamic heating and atmospheric entry. Prerequisites: Aero Eng 3171.

### **AERO ENG 5171 V/Stol Aerodynamics** (LEC 3.0)

Basic concepts of V/STOL flight. Take-off transition and landing performance, thrust vectoring. Propeller and helicopter aerodynamics. Unblown and blown flaps. Boundary layer control. Lift fans and ducted propellers. Wing-propeller interaction and thrust augmentation. Prerequisite: Aero Eng 3171.

### **AERO ENG 5212 Introduction to Finite Element Analysis** (LEC 3.0)

Variational formulation of the governing equations. Finite element model, interpolation functions, numerical integration, assembly of elements and solution procedures. Applications to solid mechanics, fluid mechanics and heat transfer problems. Two-dimensional problems. Computer implementation and use of commercial finite element codes. Prerequisites: Math 3304; senior or graduate standing. (Co-listed with Mech Eng 5212).

### **AERO ENG 5220 Advanced Mechanics of Materials** (LEC 3.0)

Comprehensive insight into mechanics of materials. Topics to include: theories of failure, torsion of noncircular sections, shear flow and shear center, unsymmetric bending, bending of curved members, beams on elastic foundation and pressurization of thick walled cylinders. Prerequisites: Civ Eng 2210, Math 3304. (Co-listed with Mech Eng 5220).

### **AERO ENG 5222 Introduction to Solid Mechanics** (LEC 3.0)

Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: Eng Mech 5211. (Co-listed with Mech Eng 5222).

### **AERO ENG 5229 Smart Materials and Sensors** (LAB 1.0 and LEC 2.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Mech Eng 5229, Elec Eng 5270 and Civ Eng 5118).

### **AERO ENG 5234 Stability of Engineering Structures** (LEC 3.0)

Solution of stability problems with applications to columns, plates and shell structures. Torsional and lateral buckling of columns. Buckling under high temperatures. Effect of imperfections introduced by a technological process on stability. Design issues related to stability requirements. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Mech Eng 5234).

### **AERO ENG 5236 Fracture Mechanics** (LEC 3.0)

Linear elastic and plastic mathematical models for stresses around cracks; concept of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5236).

### **AERO ENG 5238 Fatigue Analysis** (LEC 3.0)

The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints components and structures, design to prevent fatigue. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5238).

### **AERO ENG 5282 Introduction to Composite Materials & Structures** (LEC 3.0)

Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Civ Eng 2210. (Co-listed with Mech Eng 5282).



**AERO ENG 5307 Vibrations I** (LEC 3.0)

Equations of motion, free and forced vibration of single degree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studied. The vibration of continuous systems is introduced. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Mech Eng 5307).

**AERO ENG 5309 Engineering Acoustics I** (LEC 3.0)

Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mech Eng 3411 & 3313, or Aero Eng 3613 & Math 3304. (Co-listed with Mech Eng 5309).

**AERO ENG 5313 Intermediate Dynamics of Mechanical and Aerospace Systems** (LEC 3.0)

Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: Mech Eng 3313 or Aero Eng 3613. (Co-listed with Mech Eng 5313).

**AERO ENG 5353 Aeroelasticity** (LEC 3.0)

Study of phenomena involving interactions among inertial, aerodynamic, and elastic forces and the influence of these interactions on aircraft and space vehicle design. Some aeroelastic phenomena are: divergence, control effectiveness, control reversal, flutter, buffeting, dynamic response to rapidly applied loads, aeroelastic effects on load distribution, and static and dynamic stability. Prerequisites: Aero Eng 3251 and 3171.

**AERO ENG 5361 Flight Dynamics-Stability And Control** (LEC 3.0)

Review of static stability, dynamic equations of motion, linearized solutions, classical control design and analysis techniques, introduction to modern control. Prerequisite: Aero Eng 3361.

**AERO ENG 5449 Robotic Manipulators and Mechanisms** (LEC 2.0 and LAB 1.0)

Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Mech Eng 3313; Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972 or Comp Sci 1570. (Co-listed with Mech Eng 5449).

**AERO ENG 5478 Mechatronics** (LEC 2.0 and LAB 1.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Elec Eng 5870 and Comp Eng 5820).

**AERO ENG 5481 Mechanical and Aerospace Control Systems** (LEC 3.0)

Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mech Eng 4479 or Aero Eng 3361. (Co-listed with Mech Eng 5481).

**AERO ENG 5519 Advanced Thermodynamics** (LEC 3.0)

After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Mech Eng 2519. (Co-listed with Mech Eng 5519).

**AERO ENG 5525 Intermediate Heat Transfer** (LEC 3.0)

Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mech Eng 3525. (Co-listed with Mech Eng 5525).

**AERO ENG 5527 Combustion Processes** (LEC 3.0)

Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mech Eng 3521. (Co-listed with Mech Eng 5527).

**AERO ENG 5535 Aerospace Propulsion Systems** (LEC 3.0)

Study of atmospheric and space propulsion systems with emphasis on topics of particular current interest. Mission analysis in space as it affects the propulsion system. Power generation in space including direct and indirect energy conversion schemes. Prerequisite: Aero Eng 4535.

**AERO ENG 5570 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Mech Eng 5570, Nuc Eng 4370, Physics 4543).

**AERO ENG 5614 Spaceflight Mechanics** (LEC 3.0)

Further topics in orbital mechanics. Time equations, Lambert's problem, patched-conic method, orbital maneuvers, orbit determination, orbit design, re-entry problem. Prerequisite: Aero Eng 3613.

**AERO ENG 5715 Concurrent Engineering** (LEC 3.0)

Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mech Eng 3313 or Aero Eng 3131 and Civ Eng 2210 (Co-listed with Mech Eng 5715).

**AERO ENG 5758 Integrated Product Development** (LEC 2.0 and LAB 1.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, cost, and product support. Using a 3-D solid modeling program, students will design, analyze, and send the data base to the automated machine shop where the parts will be manufactured. The parts will then be assembled, tested and analyzed for their performance. Prerequisites: Aero Eng 3251 or Mech Eng 3708 for Design; Mech Eng 3313 for Assembly; Accompanied or preceded by Mech Eng 5653 for Manufacturing; Eng Mgt 5711 or 5714 for Cost/Product Support.

**AERO ENG 5760 Probabilistic Engineering Design** (LEC 3.0)

The course deals with uncertainties in engineering analysis and design at three levels - uncertainty modeling, uncertainty analysis, and design under uncertainty. It covers physics-based reliability analysis and reliability-based design, robustness assessment and robust design, their integration with design simulations, and their engineering applications. Prerequisite: Mech Eng 3708 or Aero Eng 3361. (Co-listed with Mech Eng 5760).

**AERO ENG 5830 Applied Computational Methods** (LEC 3.0)

Detailed study of computational methods for efficient solution of selected fluids, structures, thermodynamics, and controls problems in aerospace and mechanical engineering. Besides basic numerical techniques, topics covered include gradient-based optimization and uncertainty quantification. Prerequisite: Comp Sci 1570 or 1970 or 1981; Math 3304. (Co-listed with Mech Eng 5830).

**AERO ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects of projects in the department. Consent of instructor required.

**AERO ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Mech Eng 5001).

**AERO ENG 6010 Seminar** (LEC 0.0-1.0)

Discussion of current topics. (Co-listed with Mech Eng 6010).

**AERO ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**AERO ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**AERO ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**AERO ENG 6123 Viscous Fluid Flow** (LEC 3.0)

Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; boundary layer theory for incompressible and compressible flows; stability and transition. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Mech Eng 6123).

**AERO ENG 6131 Gas Dynamics I** (LEC 3.0)

A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandtl-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Mech Eng 6131).

**AERO ENG 6135 Turbulent Flows - Theory, Measurements and Modeling** (LEC 3.0)

Navier-Stokes equations; statistical description and mean-flow equations; behavior of free shear and wall bounded flows; the energy cascade; turbulence spectra and Kolmogorov hypothesis; measurement techniques: PIV, hot-wires, LDV; turbulence modeling for transport processes and closure schemes for RANS equations; evaluation of model constants, introduction to LES, DNS and hybrid-RANS. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Mech Eng 6135).

**AERO ENG 6137 Physical Gas Dynamics I** (LEC 3.0)

Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and Nonequilibrium gas properties and gas flows are included. Prerequisite: Mech Eng 5131 or Aero Eng 5131. (Co-listed with Mech Eng 6137).

**AERO ENG 6212 Advanced Finite Element Analysis** (LEC 3.0)

Higher order, isoparametric and mixed finite elements. Eigenvalue and time-dependent problems. Solution procedures for dynamic analysis. Implicit and explicit methods. Applications to viscous incompressible fluid and plate bending problems. Three-dimensional problems. Nonlinear finite element analysis. Practical applications using commercial software. Prerequisite: Mech Eng 5212 or Aero Eng 5212. (Co-listed with Mech Eng 6212).

**AERO ENG 6222 Theory of Elasticity** (LEC 3.0)

Formulation and study of boundary-value problems in 2-D linear elastostatics: Equilibrium and compatibility. Stress function formulations in Cartesian and polar coordinates. Curved beam, wedge and plane contact problems. Dislocations and cracks. Thermoelasticity. Prerequisites: Civ Eng 2210. (Co-listed with Mech Eng 6222).

**AERO ENG 6284 Analysis of Laminated Composite Structures** (LEC 3.0)

An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Mech Eng 6284).

**AERO ENG 6285 Mechanics Of Composite Materials** (LEC 3.0)

Effective moduli of spherical, cylindrical and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear lag and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Mech Eng 6285).

**AERO ENG 6307 Advanced Vibrations** (LEC 3.0)

Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems and random excitations. Prerequisite: Mech Eng or Aero Eng 5307. (Co-listed with Mech Eng 6307).

**AERO ENG 6313 Advanced Aerospace Mechanics** (LEC 3.0)

Current problems in aerospace dynamics are treated using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations, stability of systems, to include approximate techniques. Prerequisite: Mech Eng or Aero Eng 5313. (Co-listed with Mech Eng 6313).

**AERO ENG 6447 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Eng Mgt 6410, Sys Eng 6217 and Comp Sci 6202).

**AERO ENG 6458 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Mech Eng 6458 and Sys Eng 6215).

**AERO ENG 6479 Analysis And Synthesis Of Mechanical And Aerospace Systems** (LEC 3.0)

A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mech Eng 5481 or Aero Eng 5481. (Co-listed with Mech Eng 6479).

**AERO ENG 6481 Advanced Topics in Decision and Control** (LEC 3.0)

This course will deal with latest topics in the areas of decision and control. Course may be repeated if topics vary. Prerequisites: Aero Eng 5481 or Mech Eng 5481 or equivalent. (Co-listed with Mech Eng 6481).

**AERO ENG 6525 Heat Transfer by Conduction** (LEC 3.0)

A study of conduction of heat transfer in solids by analytical and other methods. Prerequisite: Mech Eng 5525 or Aero Eng 5525. (Co-listed with Mech Eng 6525).

**AERO ENG 6527 Heat Transfer by Convection** (LEC 3.0)

An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current topics in convection. Prerequisite: Mech Eng 5525 or Aero Eng 5525. (Co-listed with Mech Eng 6527).

**AERO ENG 6529 Heat Transfer by Radiation** (LEC 3.0)

A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Mech Eng 6529).

**AERO ENG 6614 Advanced Astrodynamics** (LEC 3.0)

Analysis of spacecraft motion using different dynamic models and perturbations. Using the state transition matrix and differential corrections technique for trajectory computation. Introduction to the three-body problem. Use of computational and numerical methods to solve astrodynamics problems. Prerequisite: Aero Eng 5614.

## Biological Sciences (BIO SCI)

**BIO SCI 5000 Special Problems** (IND 0.0-6.0)

Graduate problems or readings on specific subjects or projects in the department. Prerequisite: Consent of the instructor.

**BIO SCI 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**BIO SCI 5010 Graduate Seminar** (RSD 0.0-6.0)

Presentation and discussion of current topics in Applied and Environmental Biology.

**BIO SCI 5040 Oral Examination** (IND 0.0)

(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./PH.D students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**BIO SCI 5099 Graduate Research** (IND 0.0-15)

Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

**BIO SCI 5210 Biomaterials I** (LEC 3.0)

This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisite: Senior undergraduate standing. (Co-listed with Chem Eng 5200, MS&E 5310).

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**BIO SCI 5240 Tissue Engineering** (LEC 3.0)

The course will use problem-based case studies to introduce junior and senior undergraduate students to the principles and clinical applications of tissue engineering. Topics include the use of biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. Prerequisite: Junior or Senior standing. (Co-listed with MS&E 5210).

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**BIO SCI 5313 Pathogenic Microbiology** (LEC 3.0)

A study of medically important microorganisms. Students will learn about the properties that enable organisms to cause disease as well as the disease process within the host. Special emphasis will be placed on recent advances in the molecular genetics of host pathogen interaction. Prerequisite: Bio Sci 2213 or Civ Eng 2601.

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**BIO SCI 5323 Bioinformatics** (LEC 3.0)

The course will familiarize students with the application of computational methods to biology, as viewed from both perspectives. It will introduce problems in molecular, structural, morphological, and biodiversity informatics, and will discuss principles, algorithms, and software to address them. Prerequisites: A grade of "C" or better in both one of Bio Sci 1113 or Bio Sci 1213 and one of Comp Sci 1570 and Comp Sci 1580 or Comp Sci 1971 and Comp Sci 1981. (Co-listed with COMP SCI 5700).

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**BIO SCI 5343 Biology of Aging** (LEC 3.0)

We will discuss the proximate and ultimate mechanisms of aging, and review a few leading theories of aging with the emphases on oxidative stress and life history tradeoffs. We will take the comparative approach to study aging across species, and the interventions that extend animals' lifespan, and explore why they may or may not work on humans. Prerequisites: Bio Sci 2213.

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**BIO SCI 5353 Developmental Biology** (LEC 3.0)

Study of the patterns of development of the vertebrate embryo, the molecular mechanisms of tissue induction, and interactions among developing tissues. Prerequisite: Bio Sci 2213.

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**BIO SCI 5423 Advanced Biodiversity** (LEC 3.0)

This course focuses on the enhancement and reduction of biodiversity and modern techniques of measuring and monitoring it. Topics include biogeography, community structure, competition, predation, food webs, geology-biology relationships, environmental change, and human impact. Additional costs and a week-long field trip are required. Prerequisite: Bio Sci 2233 or Bio Sci 2263.

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**BIO SCI 5533 Pharmacology** (LEC 3.0)

The basic principles of drug action, pharmacokinetics, pharmacodynamics and toxicity. We will emphasize the actions of drugs used to treat cardiovascular and nervous system disorders. Students will review the primary literature to prepare both written and oral reports on drug actions. Prerequisite: Bio Sci 2213.

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**BIO SCI 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**BIO SCI 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**BIO SCI 6202 Problems In Applied And Environmental Biology** (LEC 0.0-3.0)

Overview of major areas of research in applied biology and environmental science with a focus on interdisciplinary approaches used on S&T campus in ongoing research. Prerequisite: Acceptance to Graduate Program.

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**BIO SCI 6210 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. Prerequisite: Graduate Standing. (Co-listed with CHEM ENG 6300, MS&E 6310).

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**BIO SCI 6223 Research Proposal Writing** (LEC 3.0)

Students will learn best practices of grant proposal writing. Students will conduct background research, prepare an annotated bibliography, brainstorm specific aims, and critique each other's writing. The course will conclude with a presentation by the student of their finished proposal. Prerequisites: Graduate standing.

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**BIO SCI 6240 Advanced Tissue Engineering** (LEC 3.0)

The course will introduce graduate students to the principles and clinical applications of tissue engineering including the use biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. A related topic term paper and oral presentation are expected. Prerequisite: Graduate standing. Prerequisite: Graduate standing. (Co-listed with MS&E 6210).

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**BIO SCI 6273 Techniques In Applied And Environmental Biology** (LEC 3.0)

Students will have the opportunity for hands on experience with the various techniques used in the modern biology laboratory. Techniques will include gene cloning, DNA sequencing, protein purification, growth and development of various model organisms, data acquisition. Prerequisite: Graduate standing.

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**BIO SCI 6313 Environmental Microbiology** (LEC 3.0)

Topics to be explored in this course will include but are not limited to microbial growth and metabolic kinetics, life in extreme conditions, biogeochemical cycling, bioremediation of contaminants, waterborne pathogens and environmental biotechnology. Prerequisite: Must be a graduate student.

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**BIO SCI 6343 Advanced Geomicrobiology** (LEC 3.0)

Microorganisms have profound effects on the environment around them and have influenced biochemical and mineralogical processes throughout time. This course will explore the impact microorganisms have on geological processes. Students will prepare a NSF-style report and defend it.

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**BIO SCI 6353 Advanced Cancer Cell Biology** (LEC 3.0)

Graduate level biology course examining cellular processes that go awry during tumorigenesis. We will discuss cell cycle controls, signal transduction pathways, DNA repair, telomerase, apoptosis, cell migration and adhesion that are altered in cancer cells. In addition to lecture, will include a weekly section to examine primary cancer literature. Prerequisite: Bio Sci 2213.

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**BIO SCI 6363 Advanced Freshwater Ecology** (LEC 3.0)

The ecology of streams, lakes, and wetlands. The course will cover the physical and chemical characteristics of freshwater environments, the diversity of life in freshwaters, biogeochemical processes, and threats to freshwater systems. Research proposal and additional readings required for graduate credit. Prerequisite: Graduate student standing.

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**BIO SCI 6373 Advanced Stem Cell Biology** (LEC 3.0)

This course will cover the fast-moving field of stem cell biology. Topics include: development and organogenesis, regeneration and repair, stem cell types and sources, pluripotency and reprogramming, stem cells and cancer, therapeutics, and ethics. Research proposal and additional readings required for graduate credit.

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**BIO SCI 6383 Advanced Toxicology** (LEC 3.0)

We will discuss the toxicity and mechanisms of action of natural and man-made toxicants. The impact of toxicants on both human health and the environment will be considered. Students will be assigned to independent literature search and write a report. Prerequisites: Bio Sci 2213.

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**BIO SCI 6413 Molecular Cell Biology** (LEC 3.0)

Advanced study of the biology of eukaryotic cells, including biomembranes and membrane transport, subcellular organelles, cellular energetics, protein sorting, cytoskeletal elements, cell to cell signalling, regulation of the cell cycle, and tissue organization. Prerequisite: Bio Sci 2213 or equivalent.

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**BIO SCI 6423 Astrobiology** (LEC 3.0)

The origins of life on early earth and the possibility of life on extraterrestrial bodies will be explored in this course through lectures and journal article discussions. In addition, the means to study extraterrestrial environments will be considered. Prerequisite: Graduate standing.

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**BIO SCI 6433 Advanced Genomics** (LEC 3.0)

An overview of the field of genomics. Topics covered include genome sequencing and annotation, transcriptomics, proteomics, metabolomics, genomic variation, and human, and several animal, plant, and microbial genome projects. Students will complete an independent genomics project that incorporates concepts and bioinformatics tools learned. Prerequisites: Students may not receive credit for both Bio Sci 4433 and Bio Sci 6433.

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**BIO SCI 6463 Bioremediation** (LEC 3.0)

'During this course, the use of microorganisms and other living organisms for the remediation of contaminated environments will be explored along with the techniques necessary for monitoring their activities. Prerequisite: Graduate standing.

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**BIO SCI 6513 Advanced Microbial Metabolism** (LEC 3.0)

A survey of the diverse metabolic properties of microorganisms. Course material will emphasize major metabolic pathways and how they relate to microbial diversity and microbial ecology. Prerequisite: Bio Sci 3313 or an equivalent course.

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**BIO SCI 6523 Advanced Biomolecules** (LEC 3.0)

Demonstration of the principles of modern biochemistry as they relate to the structure and function of the major macromolecules of the cell. An emphasis will be placed on reading and interpreting scientific literature and scientific writing. Prerequisite: Bio Sci 2213 or Chem 4610 or an equivalent course.

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**BIO SCI 6533 Advanced Neurobiology** (LEC 3.0)

A course in cellular neurobiology. Emphasis will be placed on the unique properties of neurons and other excitable cells. Topics include the structure and biophysical properties of neurons, synaptic transmission, neurochemistry, signal transduction, neuropharmacology and neurodevelopment. Students will give a 30 min class presentation on a relevant subject. Prerequisites: Students may not receive credit for both Bio Sci 4533 and Bio Sci 6533.

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**BIO SCI 6563 Advanced Global Ecology** (LEC 3.0)

This class covers ecological topics at large scales, emphasizing global scales. Topics include global energy balance, biogeochemical cycles of water, carbon, nitrogen, and other biologically important elements, and global biodiversity. Students will focus on primary literature related to global ecology. Research proposal and additional readings required. Prerequisites: Students may not receive credit for both Bio Sci 4563 and Bio Sci 6563.

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**BIO SCI 6666 Advanced Nanotechnology in Biomedicine** (LEC 3.0)

Applications of nanotechnology in life science is termed nanobiotechnology. This course describes recent development of nanotechnology in basic biological research as well as biomedical applications. In addition to attending regular lectures, graduate students will be assigned to an independent research project and present the information in the class. Prerequisites: Bio Sci 2213 and Bio Sci 2223 and graduate standing.

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## Business (BUS)

### **BUS 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department.  
Prerequisite: Admission to the MBA program.

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### **BUS 5001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

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### **BUS 5040 Oral Examination** (IND 0.0)

After completion of all other requirements, oral examinations for on-campus M.B.A./Ph.D. students may be processed during intersession. Off-campus M.B.A. students must be enrolled in oral examination and must have paid an oral examination fee at the time defense/oral examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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### **BUS 5080 Practicum** (IND 0.0-6.0)

This course is similar to the Bus 5085 Internship course. The difference is that this course is intended for students who are already employed by an organization for whom they wish to continue working. Prerequisite: Bus Core.

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### **BUS 5085 Internship** (IND 0.0-6.0)

Students apply critical thinking skills and discipline specific knowledge in a work setting based on a project designed by the advisor and employer. Activities will vary depending on the student's background and the setting. Requires major report and formal presentation to sponsoring organization. Prerequisite: Graduate standing.

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### **BUS 5099 Research** (IND 0.0-9.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings.  
Prerequisite: Permission of the instructor.

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### **BUS 5105 Graduate Management and Business Law Essentials** (LEC 1.5)

This course is an introduction to the essentials of management and business law for running a business. It's designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

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### **BUS 5115 Introduction to Individual and Group Dynamics in Business** (LEC 3.0)

This course will cover contemporary theories of business leadership styles and group dynamics. Leadership theories, group dysfunction/function, positive group interactions, change impacts, the importance of business ethics as well as the role of gender and culture on the group will be examined.

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### **BUS 5205 Graduate Accounting Essentials** (LEC 1.5)

This course is an introduction to the essentials of financial and managerial accounting for running a business. It's designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

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### **BUS 5230 Financial Statement Analysis** (LEC 3.0)

Analysis and interpretation of financial statements for profitability analysis, credit analysis, and other business analyses that rely on financial data. Introduces emerging roles of accounting analytics. Illustrates data analytics concepts and techniques to detect earning management, predict fraud, and to provide insights into other business strategies. Prerequisite: Finance 2150 or equivalent basic corporate finance knowledge.

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### **BUS 5305 Graduate Operations Management Essentials** (LEC 1.5)

This course is an introduction to the essentials of operations management for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

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### **BUS 5360 Business Operations** (LEC 3.0)

This course examines the concepts, processes, and institutions that are fundamental to an understanding of business operations within organizations. Emphasis is on the management and organization of manufacturing and service operations and the application of quantitative methods to the solution of strategic, tactical and operational problems. Prerequisites: BUS 1210 or ENG MGT 2211; at least Junior standing; and one of the following: STAT 1111, STAT 1115, STAT 1116, STAT 3111, STAT 3113, STAT 3115, or STAT 3117.

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### **BUS 5470 Human Resource Management** (LEC 3.0)

The course examines employee selection, performance appraisal, training and development, compensation, legal issues, and labor relations.  
Prerequisite: Bus 1110.

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### **BUS 5580 Strategic Management** (LEC 3.0)

Study of the formulation and implementation of corporate, business and functional strategies designed to achieve organizational objectives. Case studies and research reports may be used extensively. Prerequisites: MKT 3110 or Eng Mgt 3510; Finance 2150 or Eng Mgt 3200; Senior standing.

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### **BUS 5705 Graduate Management Information Systems Essentials** (LEC 1.5)

This course is an introduction to the essentials of management information systems for running a business. It is designed for students planning to enter the MBA program. Credit in this course cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

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**BUS 5730 Machine Learning and Artificial Intelligence for Business** (LEC 3.0)

Explores various approaches to machine learning and artificial intelligence, along with their numerous applications in business. Describes some of the many technological approaches to business problems that are considered part of machine learning and artificial intelligence, such as neural networks and deep learning. Prerequisites: IS&T 1750; or Graduate Standing, understanding of management information systems.

**BUS 5805 Graduate Mathematics and Statistics Essentials** (LEC 1.5)

This course is an introduction to the essentials of mathematics and statistics for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

**BUS 5896 Project Research** (IND 0.0-9.0)

The research project will involve students applying research techniques and discipline specific knowledge working on a project designed by the advisor, often working with a business organization. Requires major report and formal presentation to sponsoring organization. Prerequisite: Permission of the instructor.

**BUS 5910 Privacy and Information Security Law** (LEC 3.0)

Explores issues concerning the use, disclosure, and protection of information (personal, organizational, health, and financial) from a legal perspective. A focus on understanding, planning, protecting, and responding to data breaches and other information risk and threats. Case studies based on litigation are reviewed and analyzed. Assumes MIS familiarity.

**BUS 5980 Business Models for Entrepreneurship and Innovation** (LEC 3.0)

This course uses problem based learning to expand student insight into the nature, development, and application of business models. It increases the practical skills and knowledge required to generate original models of value creation for both entrepreneurial start-ups and corporate innovation. Prerequisite: Senior or graduate standing.

**BUS 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Prerequisite: Admission to the MBA program.

**BUS 6001 Special Topics** (IND 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

**BUS 6099 Research** (IND 0.0-9.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Permission of the instructor.

**BUS 6111 Advanced Business Negotiations** (LEC 3.0)

The purpose of this course is to understand the practices and processes of negotiation for negotiating successfully in a variety of settings. The course is designed to be relevant to the broad spectrum of negotiation problems faced by managers, consultants, etc. A negotiation project is also required. Prerequisite: Graduate status.

**BUS 6121 Teambuilding and Leadership** (LEC 3.0)

This class will teach students how to work well in teams and lead teams and organizations. Management, networking, presentation skills, and sustainable business practices will be covered. MBA core. Prerequisite: Graduate standing.

**BUS 6150 Advanced Customer Focus and Satisfaction** (LEC 3.0)

Major emphasis is given to the concept of customer focus, with coverage of techniques for obtaining customer needs, measuring customer satisfaction, developing products and services to satisfy customers, and maximizing the benefits of customer feedback. Individual focused research is included. Prerequisites: MKT 3110 or MKT 3105 or ENG MGT 3510. (Co-listed MKT 6150).

**BUS 6224 Managerial Accounting and Control** (LEC 3.0)

This course covers managerial accounting and its critical role in decision making, monitoring, and controlling business processes. MBA core. Prerequisite: Graduate standing.

**BUS 6425 Supply Chain and Project Management** (LEC 3.0)

This course covers supply chain management and its critical role in developing and maintaining effective and efficient processes in the organization, including operations and project management processes and principles. MBA core. Prerequisite: Graduate standing.

**BUS 6426 Integration of Business Areas** (LEC 3.0)

Students will acquire knowledge to integrate the business functions to maximize performance efficiency and effectiveness. It will be covered through case studies and readings. MBA core. Prerequisite: Graduate standing.

**BUS 6622 International Marketing** (LEC 3.0)

This course focuses on the challenges faced by business managers as they deal with a competitive global market. The course will examine various topics related to international marketing such as cultural differences, economic differences, differences in product and technical standards, global advertising, and international pricing and segmentation. MBA core. Prerequisite: Graduate standing.

**BUS 6675 Advanced International Business** (LEC 3.0)

Business concepts, analytical processes and philosophical bases for international business operations. Emphasis is on environmental dynamics, multinational business organizations, cultural and economic constraints, unique international business practices and international operations, strategy and policy. Research project required. Prerequisites: MKT 3110 or MKT 5105 or Eng Mgt 3510.

**BUS 6723 Artificial Intelligence, Robotics, and Information Systems Management** (LEC 3.0)

The course, designed for business executives, covers management of information to revitalize business processes, improve business decision-making, embrace emerging and disruptive technologies, and gain competitive advantages. The course also covers implications of AI, automation, machine learning, and robotics on business and society. MBA core. Prerequisite: Graduate standing.

**BUS 6827 Managerial Finance** (LEC 3.0)

This course covers the use of financial tools to manage the organization. The main focus is the strategic decision-making process of modern managers responsible for major financial decisions. Topics include financial policy, capital investment analysis, dividend policy, capital structure, and other contemporary corporate finance issues. MBA core. Prerequisite: Graduate standing.

**BUS 6887 Research Methods in Business and IS&T** (LEC 3.0)

This course covers quantitative and qualitative research methods for exploring the interaction between people and information technologies. The course covers techniques and tools for carrying out literature reviews, forming research goals, designing research, conducting data analyses; and preparing manuscripts and live presentations. (Co-listed with IS&T 6887).

## Ceramic Engineering (CER ENG)

**CER ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**CER ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**CER ENG 5002 Cooperative Training** (IND 1.0-3.0)

On-the-job experience gained through cooperative education with industry, with credit arranged through departmental cooperative advisor. Grade received depends on quality of reports submitted at work supervisor's evaluation.

**CER ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**CER ENG 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**CER ENG 5115 X-Ray Diffraction Analysis** (LEC 2.0 and LAB 1.0)

Theory and practical aspects of x-ray diffraction analysis are covered including diffraction theory, qualitative and quantitative analysis techniques, electronic databases, and operation of modern powder diffractometers. Students cannot receive credit for both Cer Eng 3417 and Cer Eng 5115. Prerequisite: Preceded or accompanied by Cer Eng 3410.

**CER ENG 5220 Advanced Mechanical Properties of Ceramics** (LEC 3.0 and LAB 1.0)

An advanced course to treat the theory and testing practice related to design based on the mechanical properties of ceramics. The course also includes a laboratory consisting of experiments for the characterization of the mechanical properties of ceramics. Prerequisites: Graduate standing.

**CER ENG 5230 Glass Science And Engineering** (LEC 3.0)

The development, manufacturing methods, applications, and properties of flat, fiber, container, chemical, and special purpose glasses. Composition/property relationships for glasses and nucleation-crystallization processes for glass-ceramics are also covered. Prerequisite: "C" or better grade in Cer Eng 2120.

**CER ENG 5250 Refractories** (LEC 3.0)

The manufacture, properties, uses, performance, and testing of basic, neutral and acid refractories. Prerequisite: Cer Eng 3230.

**CER ENG 5260 Dielectric And Electrical Properties Of Oxides** (LEC 3.0)

The processes occurring in inorganic materials under the influence of an electric field are considered from basic principles. Emphasis is placed on application to real systems. Prerequisite: "C" or better grade in Cer Eng 4210.

**CER ENG 5310 Advanced Ceramic Processing** (LEC 3.0)

Materials, processing and design of microelectronic ceramics are covered. Introduction to devices, triaxial ceramics, high aluminas, tape fabrication, metallizations, thick film processing and glass-to-metal seals. Prerequisites: Cer Eng 3210 & 3325.

**CER ENG 5810 Principles Of Engineering Materials** (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Met Eng 5810).

**CER ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**CER ENG 6001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.



**CER ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**CER ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**CER ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**CER ENG 6220 Optical Properties Of Materials** (LEC 3.0)

The objective of this course is to give the student a fundamental understanding of the structure-optical property relationships exhibited by isotropic and anisotropic materials. Topics will include the wave/particle nature of light, how light interacts with materials, color, and applications such as lasers, fiber optic communication systems, electro-optics, and integrated optics. Prerequisites: Physics 2135 or 2111 and Math 2222.

**CER ENG 6230 Composite Materials** (LEC 3.0)

The objective of this course is to provide students an advanced understanding of process-structure-property relationships in composites. Topics will include composite architecture, constituents, interfaces, fabrication techniques, analytical and numerical micromechanics and macromechanics, design criteria, and contemporary issues in composite materials. Prerequisite: Graduate Standing.

**CER ENG 6240 Advanced Topics On The Vitreous State** (LEC 3.0)

Modern aspects of the structure and dynamics of inorganic vitreous materials will be reviewed and applied towards understanding the macroscopic properties of glasses. Prerequisite: Graduate standing.

**CER ENG 6260 Advanced Electrical Properties of Ceramics** (LEC 3.0 and LAB 1.0)

The application of ceramic chemistry and physics to the development and evaluation of electronic, dielectric, magnetic, and optical properties. Emphasis is placed on the relationships between properties and crystal structure, defects, grain boundary nature, and microstructure. Prerequisite: Grade of "C" or better in Physics 2305.

**CER ENG 6310 Sintering And Microstructure Development** (LEC 3.0)

Theory and practice of densification, microstructure evolution, effect of processing and material factors, grain boundary migration, grain growth. Prerequisite: Graduate standing.

**CER ENG 6410 Advanced Integrated Computational Materials Engineering** (LAB 1.0 and LEC 2.0)

Students will learn of different computational tools for studying materials at different length scales. The bridging between different modeling scales will be discussed. This course has a computational laboratory to build models and run simulations. Students will complete a final project by integrating two length-scale models. Prerequisite: A grade of "B" or better grade in Math 3304.

## Chemical Engineering (CHEM ENG)

**CHEM ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required. Prerequisite: Consent of Instructor Required.

**CHEM ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**CHEM ENG 5010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**CHEM ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**CHEM ENG 5100 Intermediate Transport Phenomena** (LEC 3.0)

The similarities of flow of momentum, heat and mass transfer and the applications of these underlying principles are stressed. Course is primarily for seniors and beginning graduate students. Prerequisite: Chem Eng 3101 or graduate standing.

**CHEM ENG 5110 Intermediate Chemical Reactor Design** (LEC 3.0)

A study of homogeneous and heterogeneous catalyzed and noncatalyzed reaction kinetics for flow and batch chemical reactors. Application to reactor design is stressed. Prerequisite: Chem Eng 3150 or graduate standing.

**CHEM ENG 5120 Interfacial Phenomena In Chemical Engineering** (LEC 3.0)

The course deals with the effects of surfaces on transport phenomena and on the role of surface active agents. Topics include fundamentals of thermodynamics, momentum, heat and mass transfer at interfaces and of surfactants. Some applications are included. Prerequisite: Chem Eng 3131 or graduate standing.

**CHEM ENG 5130 Risk Assessment and Reduction** (LEC 3.0)

Safe, secure manufacturing facilities protect the health of employees and the public, preserve the environment, and increase profitability. Methods for systematically identifying hazards and estimating risk improve the safety performance and security of manufacturing facilities. Prerequisite: Senior or Graduate Standing. (Co-listed with Eng Mgt 4312).

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**CHEM ENG 5150 Intermediate Process Computing** (LAB 1.0 and LEC 2.0)

Analysis of chemical processes from model development to solution. Emphasis on numerical computational techniques and tools appropriate for ordinary and partial differential equation solution. Prerequisite: Graduate standing.

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**CHEM ENG 5161 Intermediate Molecular Engineering** (LEC 3.0)

Molecular aspects of chemical thermodynamics, transport processes, reaction dynamics, and statistical and quantum mechanics, and their treatments in molecular-based modeling and simulation approaches. Prerequisites: Chem Eng 3120 or graduate standing.

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**CHEM ENG 5170 Physical Property Estimation** (LEC 3.0)

Study of techniques for estimating and correlating thermodynamic and transport properties of gases and liquids. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5190 Plantwide Process Control** (LEC 3.0)

Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Elec Eng 5350).

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**CHEM ENG 5200 Biomaterials I** (LEC 3.0)

This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisite: Senior undergraduate standing. (Co-listed with Bio Sci 5210, MS&E 5310).

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**CHEM ENG 5210 Intermediate Biochemical Reactors** (LEC 3.0)

Application of chemical engineering principles to biochemical reactors. Emphasis on cells as chemical reactors, enzyme catalysis and production of monoclonal antibodies. Projects on special topics and presentations related to the course materials will be included. Prerequisite: Preceded or accompanied by Chem Eng 3150 or graduate standing.

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**CHEM ENG 5220 Intermediate Engineering Thermodynamics** (LEC 3.0)

Review thermodynamic principles for pure fluids and mixtures. Emphasis on applications for the chemical industry and use of fundamental relations and equations of state. Prerequisite: Senior or graduate standing.

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**CHEM ENG 5250 Isolation and Purification of Biologicals** (LEC 3.0)

Isolation and purification of biologicals with emphasis on biopharmaceuticals. Principles and applications of chromatography, lyophilization, and product formulation. Use of ultrafiltration and diafiltration in the processing of protein products. Disposable technology. Prerequisites: Chem Eng 3131 and Chem Eng 3141.

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**CHEM ENG 5300 Principles Of Engineering Materials** (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Physics 4523, Met Eng 5810, Cer Eng 5810).

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**CHEM ENG 5305 Hazardous Materials Management** (LAB 1.0)

Major themes: hazard identification and characterization; safety, health and environmental management; and the protection of safety, health and environment. Students will have an understanding of work place and environmental hazards in order to be able to facilitate their management and control. The course will include an intensive 30 hour hands-on workshop Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5310 Structure and Properties of Polymers** (LEC 3.0)

A study of the parameters affecting structure and properties of polymers. Syntheses, mechanisms, and kinetic factors are emphasized from the standpoint of structural properties. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5315 Corrosion and Its Prevention** (LEC 3.0)

A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 2110 or Cer Eng 3230. (Co-listed with Met Eng 5310).

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**CHEM ENG 5320 Introduction to Nanomaterials** (LEC 3.0)

Introduction to the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Prerequisite: Chem Eng 2300, or Met Eng 1210 or Chem 1320.

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**CHEM ENG 5330 Alternative Fuels** (LEC 3.0)

Global energy outlook and available resources are discussed. Alternative energy options and their technologies are covered. Associated environmental concerns and technology are assessed. Special emphases are placed on renewable energies, transportation fuels, energy efficiencies, and clean technologies. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 5340 Principles of Environmental Monitoring** (LEC 3.0)

This course introduces the fundamentals of particle technology, including particle characterization, transport, sampling, and processing. In addition, students will learn about the basic design of some industrial particulate systems and environmental and safety issues related to particulate handling. Prerequisites: Chem Eng 3101 or graduate standing.

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**CHEM ENG 5350 Environmental Chemodynamics** (LEC 3.0)

Interphase transport of chemicals and energy in the environment. Application of the process oriented aspects of chemical engineering and science to situations found in the environment. Prerequisite: Chem Eng 3131 or graduate standing.

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**CHEM ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CHEM ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CHEM ENG 6010 Graduate Seminar** (RSD 1.0-3.0)

Discussion of current topics. One of these topics will be expanded to write an in depth report. Prerequisites: Graduate standing.

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**CHEM ENG 6015 Lecture Series** (LEC 1.0)

Attendance of lecture series and submission of in-depth report on one of the covered topics is required for a grade. The course can be taken multiple times for a grade, with the same requirement each time, and up to three times to be counted for 6000 level course requirement. Prerequisites: Graduate standing.

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**CHEM ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus Ph.D. students may be processed during intersession. Off-campus Ph.D. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CHEM ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CHEM ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**CHEM ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CHEM ENG 6100 Advanced Chemical Engineering Thermodynamics** (LEC 3.0)

Extension of thermodynamic principles as applied to nonideal systems. Use of existing thermodynamic data and correlations with emphasis on applications of chemical engineering problems in energy, mass and momentum transfer.

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**CHEM ENG 6110 Advanced Transport Phenomena** (LEC 3.0)

Course is concerned with all aspects of transport phenomena. Complete expressions for heat, mass and momentum transfer in all three coordinate systems are applied under both laminar and turbulent conditions. Prerequisite: Chem Eng 5100.

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**CHEM ENG 6120 Applied Mathematics In Chemical Engineering** (LEC 2.0 and LAB 1.0)

An introduction to numerical methods for ordinary and partial differential equations arising in chemical engineering, bioengineering, and environmental engineering applications. Topics include finite difference and finite element methods; other numerical and analytical methods if time permits.

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**CHEM ENG 6140 Applied Optimization In Chemical Engineering** (LEC 3.0)

An introduction to modern optimization techniques having applications in engineering economics, data analysis, process design and dynamics; methods such as Fibonacci, Partan, steep ascent, geometric, mathematical and dynamic programming.

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**CHEM ENG 6150 Molecular Modeling and Simulation** (LEC 3.0)

Study of molecular-based modeling and simulation methodologies and their connections with each other and to multiscale modeling and other engineering approaches. Molecular Dynamics, Monte Carlo, Brownian Dynamics, statistical mechanics, and application cases in engineering and science are included. Prerequisite: Chem Eng 6100.

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**CHEM ENG 6180 Advanced Applications of Computational Fluid Dynamics** (LEC 3.0)

Advanced applications of CFD analyses is presented to investigate mass, momentum and heat transport in complex geometries with general initial and boundary conditions. Students will gain practical experience using commercial CFD codes and learn and apply a general algorithm for solving challenging industrial problems using tutorials. Prerequisites: Chem Eng 4150 and Chem Eng 5100.

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**CHEM ENG 6241 Intermediate Chemical Process Safety** (LEC 3.0)

The identification and quantification of risks involved in the processing of hazardous and/or toxic materials are studied. Methods to design safety systems or alter the chemical process to reduce or eliminate the risks are covered. Prerequisite: Graduate Standing.

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**CHEM ENG 6300 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. Prerequisite: Graduate Standing. (Co-listed with BIO SCI 6210, MS&E 6310).

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**CHEM ENG 6310 Nanomaterials** (LEC 3.0)

Introduction of the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Students will need to complete a project related to nanomaterials. Prerequisite: Graduate Standing. (Co-listed with MS&E 6230).

**CHEM ENG 6330 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6611 and Civ Eng 6611).

## Chemistry (CHEM)

**CHEM 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Prerequisite: Preceded or accompanied by Chem 1100 or an equivalent training program approved by S&T. Consent of instructor required.

**CHEM 5001 Special Topics** (LEC 1.0 and LAB 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**CHEM 5099 Master Research** (IND 0.0-6.0)

Master level research with the intent to lead to the preparation of a master degree thesis. Not more than six (6) credit hours allowed for graduate credit. Subject and credit to be arranged with the instructor. Preparation of a written, detailed report culminating in a thesis is required of the student. Prerequisite: Must meet departmental training requirements for laboratory safety. Consent of instructor required.

**CHEM 5100 Laboratory Safety & Hazardous Materials** (LEC 1.0)

A systematic study of safe laboratory operations and pertinent regulations of state and federal agencies. Prerequisites: Graduate standing.

**CHEM 5210 Fundamentals of Synthetic Organic Reactions** (LEC 3.0)

Fundamental organic reactions are discussed based on reaction mechanisms and synthetic applications emphasizing the synthon approach. Graduate students are required to demonstrate a higher level of learning on assessments. Prerequisite: Chem 2220.

**CHEM 5220 Synthetic Organic Chemistry** (LEC 3.0)

A systematic study of organic reactions, their mechanisms and synthetic applications. Graduate students are expected to demonstrate a higher level of proficiency during assessments. Prerequisite: Chem 2220.

**CHEM 5310 Introduction to Inorganic Chemistry** (LEC 3.0)

A study of inorganic chemistry with emphasis on physical methods. General subjects covered include: molecular structure, bonding, complexes, spectroscopy, and reaction rates. Graduate students are required to demonstrate a higher level of proficiency during assessments.

**CHEM 5410 Advanced Chemical Thermodynamics** (LEC 3.0)

A study of the laws of thermodynamics with application to chemical systems. Emphasis is placed on partial molal functions. Credit will not be given for both Chem 5410 and Chem 4410. Prerequisites: Chem 3420.

**CHEM 5420 Elemental Quantum Chemistry** (LEC 3.0)

A study of molecular structures and spectroscopy, statistical thermodynamics, kinetic theory, chemical kinetics, crystals, and liquids. Prerequisites: Math 2222; Physics 2135 or Physics 2111.

**CHEM 5430 Advanced Chemical Kinetics** (LEC 3.0)

Introductory graduate treatment of special topics of physical chemistry including statistical mechanics and kinetics. Prerequisites: Chem 3430.

**CHEM 5460 Molecular Engineering of Materials** (LEC 3.0)

This course focuses on the fundamentals of molecular engineering with an emphasis on their applications including renewable/clean energy solutions, energy storage, air/water cleaning, and optoelectronics. Topics include principles of modern physics, carbon chemistry, macromolecules, metal(covalent)-organic frameworks sol-gel processing and crystal growth. Prerequisites: Senior Standing or consent of instructor. (Co-listed with MS&E 5460).

**CHEM 5510 Introduction to Chemical Analysis** (LEC 3.0 and LAB 1.0)

Principles and analytical applications of molecular spectroscopy, chromatographic separations, mass spectrometry, and radiochemistry. A brief overview of instrument electronics, signal generation and processing, and automated analysis is also provided. Graduate students are expected to achieve a higher level of proficiency on application and assessments compared to Chem 4510 students. Prerequisites: Chem 1100, Chem 2510, Chem 2220, Chem 3430.

**CHEM 5610 Biochemistry** (LEC 3.0)

A resume of the important aspects of quantitative and physical chemistry in biochemical processes. General subjects covered include: proteins, nucleic acids, enzymes, carbohydrates and lipids. Credit may not be given for both Chem 5610 and Chem 4610. Prerequisite: Chem 2220.

**CHEM 5619 Biochemistry Laboratory** (LAB 2.0)

Experiments are integrated with the lectures and cover the chemical and physical properties of proteins, enzymes, nucleic acids, carbohydrates and lipids. Credit may not be given for both Chem 5619 and Chem 4619. Prerequisites: Preceded or accompanied by Chem 5610 and Chem 1100 or an equivalent training program approved by S&T.

**CHEM 5620 Biochemical Metabolism** (LEC 3.0)

A continuation of Chem 5610. Catabolism and anabolism of carbohydrates, lipids, proteins, and nucleic acids. Photosynthesis, oxidative phosphorylation and membranes. Credit may not be given for both Chem 5620 and Chem 4620. Prerequisite: Chem 4610 or 5610.

**CHEM 5630 Biochemical Nanotechnology** (LEC 3.0)

This course will educate on the interdisciplinary areas of bio-nanotechnology. Student will investigate the potential of nanoscience in advanced applications including DNA/protein nanotechnology, drug delivery, environmental biosensor and emerging biotechnology industries. Credit may not be given for both Chem 5630 and Chem 4630. Prerequisite: At least junior standing.

**CHEM 5640 Neurochemistry with Clinical Correlations** (LEC 3.0)

This course explores the chemical underpinnings of neurological phenomena. It covers the overall structure and function of neurons and glial cells, neurotransmission, signal transduction, and metabolism. A central focus of the course is relating these topics to processes such as learning and memory, as well as various pathological states. Prerequisites: Chem 4610.

**CHEM 5710 Environmental Monitoring** (LEC 3.0)

This course provides an overview of environmental monitoring methodologies. Discussion covers thermodynamic and kinetic processes that affect chemical transport and fate in the environment. Federal environmental regulations and remediation technologies are also covered with specific examples. Credit may not be given for both Chem 5710 and Chem 4710. Prerequisites: Chem 2210, Physics 2111.

**CHEM 5810 Introduction to Polymeric Materials** (LEC 3.0)

A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with MS&E 5810).

**CHEM 5819 Polymer Synthesis and Characterization Lab** (LAB 1.0)

Laboratory experiments dealing with polymerization syntheses and solution, bulk and solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Credit may not be given for both Chem 5819 and Chem 4819. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810 or Chem Eng 5310, preceded or accompanied by Chem 1100 or Chem 5100 or an equivalent training program approved by S&T. (Co-listed with MS&E 5819).

**CHEM 5850 Introduction to Coating Chemistry** (LEC 3.0)

Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Credit may not be given for both Chem 5850 and Chem 4850. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with MS&E 5850).

**CHEM 6000 Special Problems** (IND 0.0-6.0)

Problems or reading on specific subjects or projects in the department. Consent of instructor required.

**CHEM 6001 Special Topics** (IND 0.0 and LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**CHEM 6010 Seminar** (RSD 1.0)

Discussion of current topics.

**CHEM 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**CHEM 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**CHEM 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Must meet departmental requirements for instruction in laboratory safety. Consent of instructor required.

**CHEM 6101 Introduction to Chemistry Research** (LEC 1.0)

An introduction to chemical research topics of interest to the department presented by different faculty members. Special emphasis will also be placed on a discussion of ethics, plagiarism, codes of conduct, research notebooks, publishing, and presentations. Prerequisite: Graduate Student Status.

**CHEM 6220 Advanced Synthetic Organic Chemistry** (LEC 3.0)

A discussion of a large number of synthetically useful reactions involving enolates and enamines; nucleophilic additions to carbonyl compounds; functional group interconversions, thermal pericyclic reactions; organometallic compounds; carbocations, carbenes and free radicals as reactive intermediates; aromatic substitutions; and multistep synthesis. Prerequisite: Chem 4210 or Chem 4220.

**CHEM 6240 Physical Organic Chemistry** (LEC 3.0)

An advanced course in theoretical organic chemistry treating molecular orbital theory, free energy relationships, transition state theory, and other fundamental topics. Prerequisite: Chem 4210.

**CHEM 6250 Spectrometric Identification of Organic Compounds** (LEC 3.0)

Overview of MS and IR techniques in the characterization of organic compounds; CD/ORD; <sup>1</sup>H, <sup>13</sup>C, and heteronuclear NMR spectroscopy in the structural analysis; applications of APT, DEPT, <sup>1</sup>H-<sup>1</sup>H COSY, HETCOR, HMQC, HMBC, INADEQUATE, TOCSY, NOE AND NOESY, and dynamic NMR. Prerequisite: Chem 2220.

**CHEM 6320 Solid State Chemistry** (LEC 3.0)

The aim of this course is to build a comprehensive understanding of the chemistry of solids and its application to the materials world. Emphasis will be given on the synthesis, crystal structure and various properties of solids including electrical, optical and magnetic. Students will gain knowledge about how to correlate a property with structure. Prerequisites: Chem 2310, Chem 2320, and Chem 3410.

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**CHEM 6330 Nanomaterials Synthesis, Properties and Applications** (LEC 3.0)

Chemistry of nanomaterials. Understanding the fundamentals of nanoscience and technology. Studying the different synthesis strategies for nanomaterials and their characterization. Understanding the properties of nanomaterials and their possible applications. Introducing the concept for device fabrication. Prerequisite: Chem 4310.

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**CHEM 6350 X-ray Crystallography** (LAB 2.0 and LEC 2.0)

Molecular and crystal structure determination by single crystal x-ray diffraction methods. Brief coverage of relation to neutron and electron diffraction.

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**CHEM 6360 Bioinorganic Chemistry** (LEC 3.0)

Metallobiomolecules, including metalloenzymes and other metalloproteins; oxygen carriers; iron transport and other iron proteins; copper proteins; cancer agents and cures; nitrogen-fixation, etc. Prerequisite: Chem 4310.

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**CHEM 6380 Inorganic Materials Chemistry** (LEC 3.0)

Chemical processing of solid materials. Introduction to point groups, space groups, and x-ray diffraction. Bonding in solids - from molecular orbital theory to band theory. Nonstoichiometric materials and Kroger-Vink notation. Optical and electrical properties of semiconductors. Epitaxial growth. Quantum effects in nanophase materials. Prerequisite: Chem 4310 or permission of instructor.

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**CHEM 6420 Quantum Chemistry I** (LEC 3.0)

A rigorous introduction to the fundamental concepts and principles of quantum chemistry. Application to translational, vibrational, and rotational motion; one-electron systems. Prerequisite: Chem 3420 or equivalent.

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**CHEM 6430 Chemical Kinetics** (LEC 3.0)

An introduction to the deduction of mechanisms of homogeneous chemical reactions from rate-data. Selected topics, such as photochemistry, free-radical mechanisms, catalysis, and explosion reactions. Prerequisite: Chem 3430.

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**CHEM 6450 Spectroscopy** (LEC 3.0)

Introduction to the interaction of electromagnetic radiation with matter. Emphasis on the ultraviolet, visible, and radio portions of the spectrum. Prerequisite: Chem 3420 or equivalent.

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**CHEM 6460 Advanced Molecular Engineering of Materials** (LEC 3.0)

This advanced course focuses on the fundamentals of molecular science and engineering and their applications including renewable/clean energy solutions, energy storage, and optoelectronics. Topics include principles of carbon chemistry, macromolecules, metal(covalent)-organic frameworks, sol-gel processing, crystal growth and other advanced topics. Prerequisites: Graduate Standing or consent of instructor. (Co-listed with MS&E 6460).

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**CHEM 6480 Physical Chemistry Of Surfaces** (LEC 3.0)

Adsorption at liquid interfaces and properties of surface films. Physical and chemical adsorption on solid surfaces. Catalysis.

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**CHEM 6510 Separations** (LEC 3.0)

An in-depth study of all types of analytical and preparative scale separations. A special emphasis will be placed on chromatography and chromatographic theory. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6550 Chemical Spectroscopy** (LEC 3.0)

A study of the electronic, vibrational, rotational and nuclear magnetic resonance spectra of atoms and molecules. A basic understanding of the underlying theoretical principles and the interpretations of results is stressed. Prerequisite: Chem 4510, Chem 3420 or equivalent courses.

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**CHEM 6555 Principles And Applications Of Mass Spectrometry** (LEC 3.0)

The course covers fundamental physical principles of mass spectrometry, instrumentation, interpretation of spectra, and applications in environmental, polymer, biomedical, and forensic fields. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6570 Electrochemistry** (LEC 3.0)

Introduction to the fundamentals, methods and applications of electrochemistry. Fundamentals cover the thermodynamics/kinetics of electrode reactions, and the modes of mass transport in the electrolyte. Methods cover potentiometric, amperometric, and a.c. techniques. Applications focus on analysis and study of materials. Prerequisite: Chem 3430.

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**CHEM 6580 Mass Spectrometry of Macromolecules** (LEC 3.0)

This course will provide an overview of mass spectrometric applications in biomacromolecules and synthetic polymers; particular areas of emphasis are proteomics, genomics, pharmaceutical screening, characterization of biochemical complexes and synthetic polymers. Prerequisite: Chem 4510 or equivalent.

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**CHEM 6620 Intermediary Metabolism And Biosynthesis** (LEC 3.0)

The course covers the biosynthesis and metabolism of nucleic acids, carbohydrates, lipids and proteins. Prerequisite: Chem 4620.

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**CHEM 6650 Free Radicals In Biochemistry** (LEC 3.0)

The study of the basic principles of free radical chemistry and biochemistry. Prerequisites: Chem 2210, Chem 2220 and Bio Sci 2113.

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**CHEM 6820 Polymer Synthesis** (LEC 3.0)

The methods of organic monomer and polymer syntheses will be explored. Mechanistic and structural components, modern and current industrial methods for polymer syntheses will be discussed. Topics include linear, branched, graft, and dendritic polymers, nano-technology and macromers. Prerequisites: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; Chem 2220 or Chem 4210 or Chem 4220 or Chem 5210 or Chem 5220. (Co-listed with MS&E 6820).

**CHEM 6840 Polymer Physical Chemistry and Analysis** (LEC 3.0)

A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; thermodynamics. (Co-listed with MS&E 6840).

## Civil Engineering (CIV ENG)

**CIV ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**CIV ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**CIV ENG 5010 Seminar** (LEC 1.0)

Discussion of current topics. Prerequisite: Senior standing.

**CIV ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Elec Eng 5070).

**CIV ENG 5112 Bituminous Materials** (LEC 2.0 and LAB 1.0)

Properties, types, and grades of bituminous materials are presented. Emphasis is placed on usage, distress, surface treatment design, and asphalt concrete mix properties, behavior, design manufacture, and construction. Prerequisite: Preceded or accompanied by Civ Eng 3116.

**CIV ENG 5113 Composition And Properties Of Concrete** (LEC 3.0)

Properties of plastic and hardened concrete and the influence of cements, aggregates, water and admixtures upon these properties. The microstructure of cement gel and other factors are related to the behavior of hardened concrete under various types of loading and environments, drying shrinkage, creep and relaxation, fatigue, fracture, and durability. Introduction to statistical quality control of concrete production. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

**CIV ENG 5117 Asphalt Pavement Design** (LEC 3.0)

Structural design of flexible pavements including loading characteristics, properties of pavement components, stress distribution, and the effects of climatic variables on design criteria. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

**CIV ENG 5118 Smart Materials And Sensors** (LEC 2.0 and LAB 1.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior Standing and Math 3304. (Co-listed with Aero Eng 5229, Mech Eng 5229 and Elec Eng 5270).

**CIV ENG 5156 Pavement Design** (LEC 3.0)

Principles of flexible and rigid pavement design including stress analysis, load and environmental effects and material characteristics; Introduction to AASHTO, PCA, AI, FAA, MEPDG, and other design methods; design of overlays and drainage system; pavement performance evaluation and rehabilitation techniques. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

**CIV ENG 5203 Applied Mechanics In Structural Engineering** (LEC 3.0)

A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge, building floors, and shell roofs. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5203).

**CIV ENG 5205 Structural Analysis II** (LEC 3.0)

Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 3201 or Arch Eng 3201. (Co-listed with Arch Eng 5205).

**CIV ENG 5206 Low-Rise Building Analysis and Design** (LEC 3.0)

Characterization of various design loads, load combinations, general methodology of structural designs against lateral loads, code-oriented design procedures, distribution of lateral loads in structural systems, application of the International Building Code in design of loadbearing wall systems, building frame system and moment-resisting frame systems. Prerequisite: Preceded and/or accompanied by Civ -Arch Eng 3210 or Civ-Arch Eng 3220. (Co-listed with Arch Eng 5206).

**CIV ENG 5207 Computer Methods of Structural Analysis** (LEC 3.0)

Force and displacement matrix methods and computer methods applied to structural analysis. Analysis of indeterminate structures such as continuous beams, and two and three dimensional frames and trusses. Analysis of indeterminate structures involving temperature and support settlements effects using computer methods formulation. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5207).

**CIV ENG 5208 Structural Dynamics** (LEC 3.0)

This course deals with fundamental concepts and structural responses under dynamic loads. Hand calculations and computer methods are developed. Specific topics include resonance, beating phenomenon, equation of motion, dynamic properties, frequencies and mode shapes, and modal and Ritz analyses. Prerequisites: Mech Eng 2350 or equivalent; Civ/Arch Eng 3201 or equivalent. (Co-listed with Arch Eng 5208).

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**CIV ENG 5209 Wind Engineering** (LEC 3.0)

Introduction of wind engineering to advanced undergraduate and entry-level graduate students through structural engineering and atmospheric science fundamentals. Prerequisites: A grade of "C" or better in Civ Eng 3201. (Co-listed with Arch Eng 5001).

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**CIV ENG 5210 Advanced Steel Structures Design** (LEC 3.0)

The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3210 with a grade of "C" or better. (Co-listed with Arch Eng 5210).

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**CIV ENG 5220 Advanced Concrete Structures Design** (LEC 3.0)

The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5220).

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**CIV ENG 5222 Prestressed Concrete Design** (LEC 3.0)

Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5222).

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**CIV ENG 5231 Infrastructure Strengthening with Composites** (LEC 3.0)

The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of existing members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Civ Eng / Arch Eng 3201, Civ Eng / Arch Eng 3220. (Co-listed with Arch Eng 5231).

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**CIV ENG 5250 Air Transportation** (LAB 1.0 and LEC 2.0)

Runway configuration, airfield capacity, geometrics and terminal layout and design. Aircraft performance; navigation and air traffic control; airport planning and design; airline operations; aviation systems planning. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5260 Analysis And Design Of Wood Structures** (LEC 3.0)

A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5260).

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**CIV ENG 5270 Structural Masonry Design** (LEC 3.0)

Review of the theory and practice of analyzing low-rise masonry structures, materials and assembly types, constructability considerations, structural masonry components, repair and strengthening, and model code requirements to ensure adequate load resisting buildings. Prerequisites: Arch Eng 3201 or Civ Eng 3201. (Co-listed with Arch Eng 5270).

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**CIV ENG 5330 Unsteady Flow Hydraulics** (LEC 3.0)

The study of unsteady flow and its effect on closed water systems and in open channels. Prerequisites: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5331 Hydraulics Of Open Channels** (LEC 3.0)

The phenomena accompanying the flow of water in open channels, such as uniform and varied flow, critical conditions, backwater curves, hydraulic jump, hydraulic drop and applications are studied in detail. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5332 Transport Processes in Environmental Flows** (LEC 3.0)

Dynamics, mixing and contaminant transport in surface water bodies, including rivers and lakes. Buoyancy modifications to the mixing and dynamics of pollutant discharges and surface water bodies. Transport of sediments. Exchange processes at the air/water and sediment/water interfaces. Prerequisite: At least a "C" in Civ Eng 3330.

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**CIV ENG 5333 Intermediate Hydraulic Engineering** (LEC 3.0)

Application of fluid mechanics principles to the design. Kinematics of fluid motion, conservation of mass, linear and angular momentum, and energy. Requirements for similarity of fluid flow. Introduction to dynamics of fluid flows and viscous incompressible flows. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5335 Water Infrastructure Engineering** (LAB 1.0 and LEC 2.0)

Fundamental principles underlying comprehensive water infrastructure development; sanitary sewers, sanitary treatment facilities, stormwater sewers, stormwater detention, water power development, and hydraulic structures. The student is responsible for the planning and design of a water infrastructure development project. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5337 River Mechanics And Sediment Transport** (LEC 3.0)

Formation of rivers and the laws governing river regulation and improvements, including navigation and flood protection. Principles governing sediment transport. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

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**CIV ENG 5338 Hydrologic Engineering** (LEC 3.0)

A study of current up-to-date hydrologic techniques involving design of hydrologic input for bridges, culverts, reservoirs. Techniques involve extreme value statistics, model hydrographs, routing, etc. Prerequisite: Civ Eng 3334 with a grade of "C" or better.

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**CIV ENG 5360 Water Resources And Wastewater Engineering** (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal/systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Env Eng 5360).

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**CIV ENG 5404 Legal Aspects Of Boundary Surveying** (LEC 3.0)

The U.S. Public Land Survey System (USPLSS): original GLO survey instructions and procedures. Resurveys on the USPLSS law, standards, procedures with emphasis on Missouri. Rights in real property; statute, case and administrative law applied to boundaries. Simultaneous and sequence conveyances. Unwritten rights in real property. Riparian boundaries. Writing and interpreting boundary descriptions. Land surveyor duties and responsibilities. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5406 Surveying Systems** (LEC 3.0)

Celestial observations for azimuths. Introduction to State Plane Coordinate systems. Theory and calculations. Route surveying and geometrics, horizontal, spiral and vertical curves. Surveying aspects of residential and commercial subdivision design: lot layout, rights of way, easements, setbacks, platting, planning and zoning constraints, application of surveying software. Instrumentation: total stations, electronic levels, instrument calibrations. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5441 Professional Aspects Of Engineering Practice** (LEC 3.0)

A study of engineering registration laws, regulations, rules of professional responsibility and standards of practice. Review of causative factors of selected failures and their relationship to professional responsibility. Prerequisite: Senior standing.

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**CIV ENG 5442 Construction Planning and Scheduling Strategies** (LEC 3.0)

The goal of this course is to assist participants in gaining an understanding of schedule control techniques and the application of tools such as Primavera Software. Content areas to be addressed include: development of baseline schedules, progress monitoring and updating, recovery schedules, resource application and leveling. Prerequisite: Civ Eng or Arch Eng 4448. (Co-listed with Arch Eng 5442).

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**CIV ENG 5445 Construction Methods** (LEC 3.0)

Introduction to construction planning, selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5445).

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**CIV ENG 5446 Management Of Construction Costs** (LEC 3.0)

Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisites: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5446).

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**CIV ENG 5448 Green Engineering: Analysis of Constructed Facilities** (LEC 3.0)

Environmentally sound design and construction practices. Includes design issues, material selection and site issues that can reduce the impact on the environment caused by the construction process. LEED certification covered in depth. Prerequisites: Civ Eng 4448 or Arch Eng 4448; and Junior Standing. (Co-listed with Arch Eng 5448).

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**CIV ENG 5449 Engineering and Construction Contract Specifications** (LEC 3.0)

Legal and business aspects of contracts and contracting procedure in the construction industry. Topics include formulation of contracts in common law, engineering services contracts, and construction project contract documents and contract administration issues. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5449).

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**CIV ENG 5451 Information Technology Applications in the Construction Industry** (LEC 3.0)

Study of IT in construction industry including building information modeling and mobile sensing. Topics will include: collaborative design, clash detection, level of development, BIM contracts, automated code checking, and finally, information systems specific functions such as estimating, scheduling and cost control, lean, and integrated project delivery. Prerequisites: Civ Eng 2451.

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**CIV ENG 5452 Pre-Project Planning and Feasibility Studies** (LEC 3.0)

Overview of the studies and tools needed to make go-ahead decisions for construction projects including assimilation of client needs, surveys of project area and infrastructure conditions, scope validation, team development, project planning and cost estimation, and financial feasibility. Prerequisites: Civ Eng 4448 or both Eng Mgt 3320 and Eng Mgt 1210.

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**CIV ENG 5453 Logistics for Construction Industry** (LEC 3.0)

Overview of construction site layout, team organization, information flow, and complexities as related to: productivity improvement approaches, data gathering for analysis of construction operations, process innovation, and safety practices. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5454 Construction Technology for High-Rise Buildings** (LEC 3.0)

Overview of latest construction practices and processes for high-rise buildings from foundation to roof including advanced methods, materials, equipment and systems used for the construction of high-rise buildings, as well as the associated principles of sustainable construction. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5455 Construction Industry Best Practices** (LEC 3.0)

Overview of the best practices developed by the Construction Industry Institute (CII), and how they are implemented by the leading owners and contractors in the construction industry. Guest lecturers include CII staff and visiting industry subject matter experts. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

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**CIV ENG 5510 Geometric Design Of Highways** (LEC 2.0 and LAB 1.0)  
Development and applications of concepts of geometric design for rural and urban highways. Design controls and criteria; elements of design, including sight distance, horizontal and vertical alignment; cross-section elements; highway types; intersection design elements; types of interchanges and interchange design elements; grade separations and clearance; development of visual elements. Prerequisite: Civ Eng 3500 with grade of "C" or better.

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**CIV ENG 5513 Traffic Engineering** (LEC 3.0)  
Introduction to multimodal transportation systems and the factors that influence the planning, design, control, operation and safety of the systems will be made. This course will also include the discussion of Intelligence Transportation Systems and how emerging technologies are changing transportation systems. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5515 Advanced Traffic Operations and Capacity Analysis** (LEC 3.0)  
This course will introduce students to advanced traffic operation and capacity analysis as applied to an urban highway network. It will focus on the operations and management of freeway and arterials where a signalized intersection is one of the key elements affecting traffic flow operation and determining highway capacity. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

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**CIV ENG 5605 Environmental Systems Modeling** (LEC 3.0)  
Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Env Eng 5605).

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**CIV ENG 5619 Environmental Engineering Design** (LEC 2.0 and LAB 1.0)  
Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Env Eng 5619).

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**CIV ENG 5630 Remediation of Contaminated Groundwater and Soil** (LEC 2.0 and LAB 1.0)  
Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Env Eng 5630).

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**CIV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design** (LEC 3.0)  
Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisites: Civ Eng 3615 or Env Eng 3615.(Co-listed with Env Eng 5635).

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**CIV ENG 5640 Environmental Law And Regulations** (LEC 3.0)  
This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, AND CERCLA. Case studies will be emphasized. (Co-listed with Env Eng 5640).

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**CIV ENG 5642 Sustainability, Population, Energy, Water, and Materials** (LEC 3.0)  
This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Env Eng 5642 and Arch Eng 5642).

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**CIV ENG 5650 Public Health Engineering** (LEC 3.0)  
A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with a grade of "C" or better. (Co-listed with Env Eng 5650).

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**CIV ENG 5660 Introduction To Air Pollution** (LEC 3.0)  
Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5660).

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**CIV ENG 5662 Air Pollution Control Methods** (LEC 3.0)  
Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5662).

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**CIV ENG 5665 Indoor Air Pollution** (LEC 3.0)  
By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Env Eng 5665 and Arch Eng 5665).

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**CIV ENG 5670 Solid Waste Management** (LEC 3.0)  
A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Env Eng 5670).

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**CIV ENG 5702 Geomatics** (LEC 3.0)

Horizontal and vertical geodetic datums and networks. Theory, calculations and applications of State Plane Coordinate Systems. Introduction to Geographic and Land Information Systems: hardware and software issues; data quality and accuracy; resource, environmental, cadastral and governmental applications; databases; GIS/LIS trends. Introduction to Global Positioning Systems (GPS): Project planning, data collection, data processing and network adjustment applications, Kinematic and RealTime GPS applications, hardware and software options and costs. Prerequisite: Civ Eng 2401 with grade of "C" or better.

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**CIV ENG 5715 Intermediate Soil Mechanics** (LEC 3.0)

General principles of soil mechanics and their applications, including mineralogy, soil structure, flow through porous media, shear strength, slope stability and consolidation. Prerequisites: Civ Eng 3715 with grade of "C" or better.

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**CIV ENG 5716 Geotechnical Earthquake Engineering** (LEC 3.0)

Geotechnical earthquake hazards and mitigations, damage to structures, plate tectonics, seismicity, wave propagation, characterization of ground motions, theory of vibrations (1-DOF), effect of local soil conditions on ground response, development of design ground motions, liquefaction, dynamic lateral earth pressures and slope stability/deformation. Prerequisites: Civ Eng 3715 with a grade of "C" or better.

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**CIV ENG 5729 Foundation Engineering II** (LEC 3.0)

Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Civ Eng 4729 with a grade of "C" or better. (Co-listed with Arch Eng 5729).

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**CIV ENG 5744 Geosynthetics in Engineering** (LEC 3.0)

Geotechnical principles are applied to design of geosynthetic systems for foundation support, earth retention, drainage, and disposal of hazardous conventional wastes. Geosynthetic testing and identification. Emphasis is on design of geosynthetic earth reinforcement, roadway stabilization, filters, and waste containment systems. Prerequisite: Civ Eng 3715 with grade of "C" or better.

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**CIV ENG 5750 Transportation Applications of Geophysics** (LEC 2.0 and LAB 1.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5761 and Geophys 5761).

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**CIV ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**CIV ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**CIV ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**CIV ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**CIV ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**CIV ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**CIV ENG 6123 Pavement Management, Evaluation and Rehabilitation** (LEC 2.0 and LAB 1.0)

Advanced knowledge of pavement performance; pavement evaluation; implementation of pavement management at network and project levels; maintenance and rehabilitation strategies; life-cycle cost analysis. Prerequisites: Graduate Standing.

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**CIV ENG 6131 Fundamentals of Rheology & Self Consolidating Concrete** (LEC 3.0)

Discuss various rheological testing protocols & models applicable to cement-based materials and present relationships between rheological parameters and workability of grout and concrete. Understand key performance characteristics of specialty concretes, including self-consolidating, underwater, pumped & shotcrete. Prerequisites: Graduate Standing.

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**CIV ENG 6141 Principles of Rheology** (LEC 3.0)

The relation of the flow/deformation behavior of materials (liquids and flowing solids) and their internal structure is studied theoretically. The tools and most common procedures to measure the rheological properties of these materials are introduced and demonstrated. Different applications of rheology are presented and special problems discussed. Prerequisites: Civ Eng 2210 and Civ Eng 3330.

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**CIV ENG 6201 Analysis And Design Of Plates And Shells I** (LEC 3.0)

Fundamental theories of bending and buckling of plates for practical applications in analysis and design of bridge and building floors, highway and airport pavements, and structural plate components. Shell theory with application to tanks, pressure vessels, shell roofs, and folded plate construction. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6205 Structural Dynamics and Earthquake Engineering** (LEC 3.0)  
Behavior of structural materials, elements, and systems under earthquake loads; computer methods for response analysis of lumped and distributed mass models, eigensolution techniques, response spectral analysis, design of 2-D and 3-D seismic resistant structures with current design codes. Prerequisite: Civ/Arch Eng 5208 or equivalent.

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**CIV ENG 6206 Stochastic Theory of Structural Dynamics** (LEC 3.0)  
Probability theory and application in structural dynamics. Stochastic models for earthquake-induced forces and wind effects on structure. Solutions for linear and nonlinear structures. Reliability-based evaluation of structural performance under random loading. Simulation of stochastic processes. Prerequisites: Math 3304; Mech Eng 5307 or Civ Eng 6205, and Stat 3115.

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**CIV ENG 6207 Finite Element Application in Structural Design** (LEC 3.0)  
Concepts of analysis and design. Generalized coordinate models and isoparametric derivations for one, two, and three dimensional elements. Systems with plate and shell elements. Structural instability problems. Elastic and inelastic systems for static and dynamic loads. Studies of computer programs.

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**CIV ENG 6208 Analysis Of Nonlinear Structures** (LEC 3.0)  
Inelastic behavior of structural members and connections; formulation of various models for steel and reinforced concrete including elasto-plastic, bilinear, trilinear, Ramberg-Osgood, Cheng-Mertz, and Cheng-Lou; matrix analysis of 2-D and 3-D building structures for geometric and material nonlinearity; dynamic and stability analysis. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6211 Plastic Analysis And Design Of Metal Structures** (LEC 3.0)  
Behavior of engineering materials in the inelastic stress range. Analysis and design of elementary structural members and frames.

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**CIV ENG 6213 Advanced Design in Steel and Lightweight Structures** (LEC 3.0)  
A critical evaluation of the theories of design and actual behavior of metal components and their connections. The basis of the development of the pertaining codes will be considered. Prerequisite: Preceded or accompanied by Civ Eng 5207.

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**CIV ENG 6221 Advanced Behavior Of Reinforced And Prestressed Concrete** (LEC 3.0)  
Behavior of reinforced and prestressed concrete sections, members and wall/shell-type elements subjected to bending, axial load, shear and torsion. Confinement of concrete. Various truss model theories applicable to main members and strut-tie model applicable to disturbed regions, joints, and connections. Prerequisite: Civ Eng 3220 with grade of "C" or better.

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**CIV ENG 6331 Advanced Hydraulics And Hydraulic Engineering** (LEC 3.0)  
Studies in the field of hydraulic engineering to fit the needs of a particular student or class. Each student makes a complete design of a hydraulic development in one of the following fields; water power, sanitation, river and harbor projects. Prerequisite: Civ Eng 3330.

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**CIV ENG 6335 Hydraulic Structures** (LEC 3.0)  
Gravity, arch, multiple arch, and buttress dams including appurtenances such as spillways, penstocks and gates. Latter part of course is designed to needs of the individual student with applications to river and harbor structures, canal and irrigation structures, and sewage structures. Prerequisites: Civ Eng 3220 and 3330.

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**CIV ENG 6338 Advanced Hydrology** (LEC 3.0)  
A study of methods used in modern hydrologic analysis and design. Items of study include hydrography analysis, maximum possible storm, infiltration, design flood determination and project feasibility. Prerequisite: Civ Eng 3333.

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**CIV ENG 6340 Urban Hydrology** (LEC 3.0)  
Studies of the influence of urban areas on their hydrology. Special emphasis on the principles of spatially varied unsteady flow. Model hydrographs leading toward determination of design storm flow are utilized to obtain information necessary for design of storm sewers, channels, and hydraulic structures common to urban areas. Prerequisite: Civ Eng 3333.

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**CIV ENG 6442 Construction Administration, Planning and Control** (LEC 3.0)  
Study of construction project development and execution, ranging from preliminary engineering to project turnover. Key topics include bidding strategies, quality control, conceptual estimating, scheduling, progress and cost control, value engineering, safety and construction productivity. Prerequisite: Preceded or accompanied by Civ Eng 5445.

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**CIV ENG 6443 Contract Formulation And Project Delivery Systems** (LEC 3.0)  
Project life-cycle planning and management. Roles and responsibilities of contract participants. Construction contract formulation. Obtaining work by negotiating and by bidding. Forms and variations of project delivery systems. Prerequisite: Civ Eng 5445 or Civ Eng 5449.

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**CIV ENG 6445 Advanced Construction Engineering** (LEC 3.0)  
Study of the temporary structures and plant used in construction. Key topics include legal implications, codes and regulations, falsework, slipforming, bridge construction supports, and protection of adjacent facilities. Prerequisite: Preceded or accompanied by Civ Eng 5445.

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**CIV ENG 6501 Transportation Planning** (LEC 3.0)  
Study of urban development, mobility patterns, and the transportation network. Transportation modeling techniques; transportation control plans to improve air quality; consideration of the transportation disadvantaged; transportation planning in smaller cities and rural areas. Access management and site impact analysis of traffic generators. Prerequisite: Civ Eng 5513 or consent of instructor.

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**CIV ENG 6505 Traffic Modeling and Simulation** (LEC 3.0)  
Fundamentals of system simulation, components of a simulation model, traffic flow simulation approaches, traffic flow simulation software and their applications, building simulation models, verification and validation of a simulation model, output analysis, variance reduction techniques, role of simulation in Intelligent Transportation Systems (ITS). Prerequisites: Stat 3113, Civ Eng 3500 preceded or accompanied by Civ Eng 5513.

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**CIV ENG 6509 Traffic Flow Theory and Characteristics** (LEC 3.0)

This course will cover advanced theories of traffic flow, traffic flow characteristics, statistical distributions of traffic flow parameters, traffic stream models, car following models, shock wave analysis, queuing analysis, traffic flow models for intersections, traffic simulation. Prerequisites: Preceded or accompanied by Civ Eng 5513, knowledge of statistics, graduate standing or consent of instructor.

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**CIV ENG 6511 Transportation Systems Analysis** (LEC 3.0)

Concepts and principles fundamental to the planning, design, operation, and management of transportation systems using a systems perspective to transportation problems. Concepts from economics, engineering, operations research, management, psychology, and public policy analysis are used throughout. Topics include linear and non-linear programming, dynamic programming, supply-demand microeconomic framework, analysis of transportation demand, system performance, network equilibrium, simulation and associated case studies. Prerequisite: Civ Eng 5513.

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**CIV ENG 6600 Chemical Principles In Environmental Engineering** (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Env Eng 6600).

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**CIV ENG 6601 Biological Principles In Environmental Engineering Systems** (LEC 2.0 and LAB 1.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Env En 6601).

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**CIV ENG 6602 Environmental Chemistry** (LAB 1.0 and LEC 2.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Env En 6602).

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**CIV ENG 6608 Environmental Engineering Analysis Laboratory** (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Env Eng 6608).

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**CIV ENG 6611 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6611 and Chem Eng 6330).

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**CIV ENG 6612 Biological Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion processes. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6612).

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**CIV ENG 6671 Industrial And Hazardous Waste Treatment** (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Env En 6671).

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**CIV ENG 6712 Computer Modeling in Geotechnical Engineering** (LEC 3.0)

Survey of computer methods of analyzing and modeling complex geotechnical engineering problems. Computer applications, data analysis, and result interpretations. Topics include constitutive modeling, foundation engineering, seepage, unsaturated flow problem, slope stability analysis, consolidation, excavation, tunneling, and dynamic soil-structure interaction. Prerequisite: Civ Eng 3715 and graduate standing.

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**CIV ENG 6713 Dynamics of Earth Materials** (LEC 3.0)

Theory of vibration, spectral response, site-specific response spectra, detailed design of retaining structures, pile and machine foundations, soil structure interaction. Dynamic soil properties, including degradation of soil properties and liquefaction, seismic slope stability analysis problem solving. Select research topics and use of computer codes. Prerequisite: Preceded or accompanied by Civ Eng 5715.

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**CIV ENG 6714 Measurement Of Soil Properties** (LEC 2.0 and LAB 1.0)

Laboratory determination of soil properties with emphasis on practical. Applications of test data. Tests include classification, atterberg limits, consolidation, compaction, triaxial shear tests with pore pressure measurement, and direct shear tests. Preparation of technical reports. Prerequisites: CIV ENG 3715.

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**CIV ENG 6715 Advanced Soil Mechanics** (LEC 3.0)

Advanced topics and recent advances in theoretical soil mechanics. Topics may include stress distribution, failure theories, shear failure in ideal soils, consolidation and settlement, physico-chemical properties, and clay mineralogy. Prerequisite: Civ Eng 5715.

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**CIV ENG 6716 Soil Stabilization** (LEC 3.0)

The application of mineralogical and physicochemical principles to soil stabilization problems and stabilization techniques for highway and foundation applications. Prerequisite: Civ Eng 5715.

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**CIV ENG 6717 Earth Dams And Related Problems** (LEC 3.0)

The exploration for and selection of site and materials, seepage analysis, slope stability and design, embankment design, compaction, instrumentation and construction operations as they pertain to earth and rockfill dams. Prerequisite: Civ Eng 5715.

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**CIV ENG 6729 Foundation Engineering III** (LEC 3.0)

A critical study of modern concepts of foundation engineering including current procedure for the application of soil mechanics principles to the design of foundations, embankments and retaining structures. Case histories will be emphasized with the student making successive design decisions.

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**CIV ENG 6760 Inca Civilization Geotechnical Engineering Practices** (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Geo Eng 6407).

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**CIV ENG 6801 Advanced Concrete Science and Technology** (LEC 3.0)

The course covers advanced notions of concrete science and technology. It discusses various aspects related to cement manufacturing, cement hydration and microstructure, use of supplementary cementitious materials and chemical admixtures, rheology and workability, mechanical properties, dimensional stability, durability, and sustainability of concrete. Prerequisites: Civ Eng 5113 or equivalent; or consent of the instructor with Graduate Standing. (Co-listed with Arch Eng 6801).

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## Computer Engineering (COMP ENG)

**COMP ENG 5000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**COMP ENG 5001 Special Topics** (LEC 1.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**COMP ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Elec Eng 5070, Civ Eng 5070).

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**COMP ENG 5099 Special Research And Thesis** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

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**COMP ENG 5110 Principles of Computer Architecture** (LEC 3.0)

Principles of performance measurement and instruction set design; advanced issues in pipelining; instruction level parallelism (dynamic scheduling, branch prediction, multi-issue processors); memory hierarchies for superscalar processors; multiprocessors; multi-threading; storage systems; and interconnection networks. Prerequisite: Comp Eng 3110. (Co-listed with Comp Sci 5803).

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**COMP ENG 5120 Digital Computer Design** (LEC 3.0)

Organization of modern digital computers; design of processors, memory systems and I/O units, hardware-software tradeoffs in different levels of computer system design. Prerequisites: COMP ENG 3150 and COMP ENG 3151.

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**COMP ENG 5130 Advanced Microcomputer System Design** (LEC 3.0)

The design of digital systems based on advanced microprocessors. Introduction to microcomputer logic development systems. I/O interfaces. Assembly and high level language tradeoffs. Hardware and software laboratory projects required. Prerequisites: COMP ENG 5110.

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**COMP ENG 5151 Digital Systems Design Laboratory** (LEC 2.0 and LAB 1.0)

Design of 32-bit microcontroller based systems. Topics include the instruction set architecture of a 32-bit microcontroller, assembly language and C programming, using microcontroller peripherals for communication, measurement and control. Student designs, programs and tests microcontroller based projects. Prerequisites: Comp Eng 3150 or Comp Eng 5110.

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**COMP ENG 5160 Embedded Processor System Design** (LEC 3.0)

Development of hardware and software for embedded systems, including real-time operating systems, advanced programming, communication schemes, hardware peripherals and sensors, control methodologies, printed-circuit board design, interrupts, microcontrollers, and hardware-software co-design. One or more team design projects. Prerequisites: COMP ENG 3150 or equivalent or 80x51 processor experience.

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**COMP ENG 5170 Real-Time Systems** (LEC 3.0)

Introduction to real-time (R-T) systems and R-T kernels, also known as R-T operating systems, with an emphasis on scheduling algorithms. The course also includes specification, analysis, design and validation techniques for R-T systems. Course includes a team project to design an appropriate R-T operating system. Prerequisites: COMP ENG 3150 or COMP SCI 3800. (Co-listed with Comp Sci 5205).

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**COMP ENG 5210 Introduction To VLSI Design** (LEC 3.0)

An introduction to the design and analysis of digital integrated circuits (ICs). Topics include basic manufacturing techniques, transistor-level design and analysis of logic and memory circuits, logic timing, and parasitics. Computer aided design tools are used to develop circuits in the lab. Prerequisites: Elec Eng 2200 and Comp Eng 2210.

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**COMP ENG 5220 Digital System Modeling** (LEC 3.0)

Digital system modeling for simulation, synthesis, and rapid system prototyping. Structural and behavioral models, concurrent and sequential language elements, resolved signals, generics, configuration, test benches, processes and case studies. Prerequisite: Comp Eng 2210 with a grade of "C" or better.

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**COMP ENG 5230 Optical Computing** (LEC 3.0)

Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisite: Comp Eng 2210 or equivalent. (Co-listed with Elec Eng 5250).

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**COMP ENG 5310 Computational Intelligence** (LEC 3.0)

Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Elec Eng 5810 and Sys Eng 5211).

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**COMP ENG 5410 Introduction to Computer Communication Networks** (LEC 3.0)

Design of computer networks with emphasis on network architecture, protocols and standards, performance considerations, and network technologies. Topics include: LAN, MAN, WAN, congestion/flow/error control, routing, addressing, broadcasting, multicasting, switching, and internetworking. A modeling tool is used for network design and simulation. Prerequisites: Comp Eng 3150 or computer hardware competency and Stat 3117 or Stat 3115 or Stat 5643 or equivalent.

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**COMP ENG 5420 Introduction to Network Security** (LEC 3.0)

This course examines basic issues in network management, testing, and security; it also discusses key encryption, key management, authentication, intrusion detection, malicious attack, and insider threats. Security of electronic mail and electronic commerce systems is also presented. Prerequisite: Comp Eng 5410 or Comp Sci 5600.

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**COMP ENG 5430 Wireless Networks** (LEC 2.0 and LAB 1.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Elec Eng 5430 and Sys Eng 5323.)

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**COMP ENG 5450 Digital Image Processing** (LEC 3.0)

Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5450).

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**COMP ENG 5460 Machine Vision** (LEC 3.0)

Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Elec Eng 5460).

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**COMP ENG 5510 Fault-Tolerant Digital Systems** (LEC 3.0)

Design and analysis of fault-tolerant digital systems. Fault models, hardware redundancy, information redundancy, evaluation techniques, system design procedures. Prerequisites: Comp Eng 2210 and Comp Eng 2211.

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**COMP ENG 5610 Real-Time Digital Signal Processing** (LEC 2.0 and LAB 1.0)

Introduction to the use of programmable DSP chips. Includes real-time data acquisition, signal generation, interrupt-driven programs, high-level language, and assembly level routines. Applications to real-time systems are also presented. Prerequisite: Elec Eng 3400 or Elec Eng 3410.

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**COMP ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design** (LEC 3.0)

Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Elec Eng 5620).

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**COMP ENG 5803 Mathematical Logic I** (LEC 3.0)

A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Comp Sci 5203, Philos 4354 and Math 5154).

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**COMP ENG 5820 Mechatronics** (LAB 1.0 and LEC 2.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Elec Eng 5870).

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**COMP ENG 5880 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Elec Eng 5880).

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**COMP ENG 6000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department.  
Prerequisite: Consent of the instructor.

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**COMP ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title. Prerequisite: Consent of the instructor.

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**COMP ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except for the dissertation, and are away from the campus, must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**COMP ENG 6099 Special Research and Thesis** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of the instructor required.

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**COMP ENG 6110 Advanced Computer Architecture I** (LEC 3.0)

Advanced topics in computer structures, parallel processors, and computer networks. Emphasis on their design, applications, and performance. Prerequisite: Comp Eng 5110 or Comp Eng 5120. (Co-listed with Comp Sci 6801).

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**COMP ENG 6120 Advanced Computer Architecture II** (LEC 3.0)

Continuation of Computer Engineering 6110. Prerequisites: COMP ENG 6110.

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**COMP ENG 6210 Digital Logic** (LEC 3.0)

Digital logic analysis, synthesis and simulation. Design automation of digital systems. Prerequisites: Comp Eng 2210 and Comp Eng 2211.

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**COMP ENG 6230 Advanced VLSI Design** (LEC 3.0)

Advanced topics in chip-level VLSI design, including issues related to high-performance, low-power, analog and mixed-signal circuits, reliability, noise and coupling mechanisms, computer aided design tools, and recent advances and trends in the field. Prerequisite: Comp Eng 5210 is required.

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**COMP ENG 6302 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 301 Introduction to Data Mining. (Co-listed with Comp Sci 6402 and Sys Eng 6216).

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**COMP ENG 6310 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Mech Eng 6447, Aero Eng 6447, Eng Mgt 6410, Comp Sci 6202 and Sys Eng 6217).

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**COMP ENG 6320 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Elec Eng 6360, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

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**COMP ENG 6330 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Elec Eng 6830, Sys Eng 6214, Comp Sci 6405, Stat 6239).

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**COMP ENG 6410 Modeling Complex Systems** (LEC 3.0)

Engineering Systems of today are non-linear, distributed, global, and adaptive to their environment in both space and time, thereby creating emergent behaviors. This course covers the current modeling tools and techniques used in modeling and architecting these complex systems. Prerequisites: Graduate Standing. (Co-listed with SYS ENG 6321).

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**COMP ENG 6420 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Elec Eng 6430 and Sys Eng 6324).

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**COMP ENG 6430 High Speed Networks** (LAB 1.0 and LEC 2.0)

A state-of-the-art survey of high-speed networks, modeling and simulation, quality of service (QoS) for multimedia applications and management schemes, TCP congestion control, ATM and Internet traffic management, Internet Service Architecture (ISA), and Internet routing protocols. Prerequisites: Comp Eng 5410 and hardware competency for ECE students, Comp Sci 4600 for computer science students, or consent of the instructor.

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**COMP ENG 6440 Network Performance Analysis** (LEC 3.0)

Provides an introduction to performance modeling and analysis of computer networks. Topics include stochastic processes; performance measurement and monitoring; quantitative models for network performance, e.g., Markovian models for queues; simulation; and statistical analysis of experiments. Prerequisites: Comp Eng 5410 or Comp Sci 4600; Stat 3117 or 5643. (Co-listed with Comp Sci 6602).

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**COMP ENG 6510 Resilient Networks** (LEC 3.0)

This course presents reliability and fault tolerance for network-centric systems, including models, metrics, and analysis techniques. This course also concentrates on security, including technical tools and methods for audit and assessment as well as management and policy issues. Prerequisites: Sys Eng 6410, Comp Eng 6410, or Comp Eng 5420. (Co-listed with SYS ENG 6322).

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## Computer Science (COMP SCI)

**COMP SCI 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**COMP SCI 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**COMP SCI 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**COMP SCI 5099 Research** (IND 0.0-16)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**COMP SCI 5100 Agile Software Development** (LEC 3.0)

Understand principles of agile software development and contrast them with prescriptive processes. Specifically: Eliciting, organizing, and prioritizing requirements; Design processes; Understand how a particular process promotes quality; Estimate costs and measure project progress and productivity. Prerequisite: A "C" or better grade in Comp Sci 3100.

**COMP SCI 5101 Software Testing And Quality Assurance** (LEC 3.0)

It covers unit testing, subsystem testing, system testing, object-oriented testing, testing specification, test case management, software quality factors and criteria, software quality requirement analysis and specification, software process improvement, and software total quality management. Prerequisite: A "C" or better grade in Comp Sci 2500.

**COMP SCI 5102 Object-Oriented Analysis And Design** (LEC 3.0)

This course will explore principles, mechanisms, and methodologies in object-oriented analysis and design. An object-oriented programming language will be used as the vehicle for the exploration. Prerequisite: A "C" or better grade in Comp Sci 2500.

**COMP SCI 5200 Analysis Of Algorithms** (LEC 3.0)

The purpose of this course is to teach the techniques needed to analyze algorithms. The focus of the presentation is on the practical application of these techniques to such as sorting, backtracking, and graph algorithms. Prerequisite: A "C" or better grade in Comp Sci 2500.

**COMP SCI 5201 Object-Oriented Numerical Modeling I** (LEC 3.0)

A study of object-oriented modeling of the scientific domain. Techniques and methodologies will be developed enabling the student to build a class library of reusable software appropriate for scientific application. Applications will be drawn from mechanics, finance, and engineering. Prerequisites: A grade of "C" or better in both Comp Sci 3200 and Comp Sci 1575; a grade of "C" or better in one of Math 3108, 3103, 3329.

**COMP SCI 5202 Object-Oriented Numerical Modeling II** (LEC 3.0)

A continued study of object-oriented modeling of the scientific domain. Advanced applications include models posed as balance laws, integral equations, and stochastic simulations. Prerequisite: A "C" or better grade in Comp Sci 5201.

**COMP SCI 5203 Mathematical Logic I** (LEC 3.0)

A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering. Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Math 5154, Philos 4354 and Comp Eng 5803.)

**COMP SCI 5204 Regression Analysis** (LEC 3.0)

Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 2222 and one of Stat 3111, 3113, 3115, 3117, or 5643. (Co-listed with Stat 5346).

**COMP SCI 5204H Regression Analysis-H** (LEC 3.0)**COMP SCI 5205 Real-Time Systems** (LEC 3.0)

Introduction to real-time (R-T) systems and R-T kernels, also known as R-T operating systems, with an emphasis on scheduling algorithms. The course also includes specification, analysis, design and validation techniques for R-T systems. Course includes a team project to design an appropriate R-T operating system. Prerequisites: COMP ENG 3150 or COMP SCI 3800. Co-listed with Comp Eng 5170.

**COMP SCI 5300 Database Systems** (LEC 3.0)

This course introduces the advanced database concepts of normalization and functional dependencies, transaction models, concurrency and locking, timestamping, serializability, recovery techniques, and query planning and optimization. Students will participate in programming projects. Prerequisite: A "C" or better grade in both Comp Sci 1200 and Comp Sci 2300.

**COMP SCI 5400 Introduction To Artificial Intelligence** (LEC 3.0)

A modern introduction to AI, covering important topics of current interest such as search algorithms, heuristics, game trees, knowledge representation, reasoning, computational intelligence, and machine learning. Students will implement course concepts covering selected AI topics. Prerequisite: A "C" or better grade in Comp Sci 2500.

**COMP SCI 5401 Evolutionary Computing** (LEC 3.0)

Introduces evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory (e.g., genetic algorithms), capable of solving complex problems for which other techniques fail. Students will implement course concepts, tackling science, engineering and/or business problems. Prerequisite: A "C" or better grade in both Comp Sci 2500 and in a Statistics course.

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**COMP SCI 5402 Introduction to Data Mining** (LEC 3.0)

The key objectives of this course are two-fold: (1) to teach the fundamental concepts of data mining and (2) to provide extensive hands-on experience in applying the concepts to real-world applications. The core topics to be covered in this course include classification, clustering, association analysis, data preprocessing, and outlier/novelty detection. Prerequisites: A grade of "C" or better in all of Comp Sci 2300, Comp Sci 2500, and one of Stat 3113, Stat 3115, Stat 3117 or Stat 5643.

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**COMP SCI 5403 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Eng 5880 and Elec Eng 5880).

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**COMP SCI 5404 Introduction to Computer Vision** (LEC 3.0)

This course introduces foundational theories and analysis methods in computer vision. Topics will include camera model and geometry, description of visual features, shape analysis, stereo reconstruction, motion and video processing, and visual object recognition. Prerequisite: A "C" or better grade in both Math 3108 and Comp Sci 2500.

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**COMP SCI 5405 Java Gui & Visualization** (LEC 3.0)

Fundamentals of Java Swing Foundation Classes, Java System Language Specifics, Graphical User Interfaces, Images, Audio, Animation, Networking, and Threading. Visualization of Algorithms. GUI Elements include Event Driven Programming, Interaction with Mouse and KeyBoard, Window Managers, Frames, Panels, Dialog Boxes, Borders. Prerequisite: A "C" or better grade in Comp Sci 2500 or equivalent.

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**COMP SCI 5406 Interactive Computer Graphics** (LEC 3.0)

Applications and functional capabilities of current computer graphics systems. Interactive graphics programming including windowing, clipping, segmentation, mathematical modeling, two and three dimensional transformations, data structures, perspective views, antialiasing and software design. Prerequisite: A "C" or better grade in both Comp Sci 3200 and Comp Sci 2500.

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**COMP SCI 5500 The Structure of a Compiler** (LEC 3.0)

Review of Backus normal form language descriptors and basic parsing concepts. Polish and matrix notation as intermediate forms, and target code representation. Introduction to the basic building blocks of a compiler: syntax scanning, expression translation, symbol table manipulation, code generation, local optimization, and storage allocation. Prerequisite: A "C" or better grade in both Comp Sci 3500 and Comp Sci 2500.

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**COMP SCI 5600 Computer Networks** (LEC 3.0)

This course focuses on the Internet and the general principles of computer networking. It covers the TCP/IP model from the application layer to the link layer in a top-down approach. It also exposes students to multimedia networking, network security, wireless and mobile networks. It is a networking class targeted for entry-level graduate students. This course has additional requirements beyond CS4600 on network performance modeling and analysis, development and implementation of complex communication protocols. Credit will not be given if previously have taken CS4600 or CpE 4410/5410. Prerequisite: A "C" or better grade in Comp Sci 3800.

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**COMP SCI 5601 Security Operations & Program Management** (LEC 3.0)

An overview of information security operations, access control, risk management, systems and application life cycle management, physical security, business continuity planning, telecommunications security, disaster recovery, software piracy, investigations, ethics and more. There will be extensive reporting, planning and policy writing. Prerequisite: A "C" or better grade in all of: operating systems, computer networking, and a writing emphasized course.

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**COMP SCI 5602 Introduction to Cryptography** (LEC 3.0)

Introduces fundamentals of modern cryptography. Topics include basic number theory, public & private key encryption schemes, cryptographic hash functions, message authentication codes, elliptic curve cryptography, Diffie-Hellman key agreements, digital signatures, PUFs, quantum cryptography, and generation of prime numbers and pseudo-random sequences. Prerequisites: A grade of "C" or better in COMP SCI 5200 or a grade of "B" or better in COMP SCI 2500.

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**COMP SCI 5700 Bioinformatics** (LEC 3.0)

The course will familiarize students with the application of computational methods to biology, as viewed from both perspectives. It will introduce problems in molecular, structural, morphological, and biodiversity informatics, and will discuss principles, algorithms, and software to address them. Prerequisites: A grade of "C" or better in both one of Bio Sci 1113 or Bio Sci 1213 and one of Comp Sci 1570 and Comp Sci 1580 or Comp Sci 1971 and Comp Sci 1981. (Co-listed with Bio Sci 5323).

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**COMP SCI 5800 Distributed Computing** (LEC 3.0)

This is an introduction to the fundamentals of distributed computing. Topics include a review of communication between distributed processes, causality, distributed state maintenance, failure detection, reconfiguration and recovery, distributed mutual exclusion, clock synchronization, and leader election. Students will implement select course concepts. Prerequisites: A grade of "C" or better in both Comp Sci 3800 and Comp Sci 2500.

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**COMP SCI 5801 The Structure Of Operating Systems** (LEC 3.0)

The hardware and software requirements for operating systems for uniprogramming, multiprogramming, multiprocessing, time sharing, real time and virtual systems. The concepts of supervisors, interrupt handlers, input/output control systems, and memory mapping are discussed in detail. Prerequisite: A "C" or better grade in Comp Sci 3800.

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**COMP SCI 5802 Introduction to Parallel Programming and Algorithms** (LEC 3.0)

Parallel and pipelined algorithms, architectures, network topologies, message passing, process scheduling and synchronization. Parallel programming on clusters. Cost, speedup and efficiency analysis. Prerequisite: A "C" or better grade in both Comp Sci 3800 and Comp Sci 2500.

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**COMP SCI 5803 Introduction to High Performance Computer Architecture** (LEC 3.0)

Overviews high performance architecture of computing systems and covers various architectural/hardware and software/algorithmic means that enhance performance. Uniprocessor and concurrent systems are investigated. Various computational models are studied and linked to commercial systems. Prerequisite: A "C" or better grade in both Comp Eng 3150 and Comp Sci 2500. (Co-listed with Comp Eng 5110).

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**COMP SCI 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**COMP SCI 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**COMP SCI 6010 Seminar** (RSD 1.0)

Discussion of current topics.

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**COMP SCI 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**COMP SCI 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**COMP SCI 6099 Research Special Topics** (IND 0.0-16)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**COMP SCI 6100 Software Engineering II** (LEC 3.0)

A quantitative approach to measuring costs/productivity in software projects. The material covered will be software metrics used in the life cycle and the student will present topical material. Prerequisite: A "C" or better grade in Comp Sci 3100.

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**COMP SCI 6101 Software Requirements Engineering** (LEC 3.0)

This course will cover advanced methods, processes, and technique for discovering, analyzing, specifying and managing software requirements of a software system from multiple perspectives. It will discuss both functional and non-functional requirements analysis. Prerequisite: A "C" or better grade in Comp Sci 3100.

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**COMP SCI 6102 Model Based Systems Engineering** (LEC 3.0)

Provides the student with understanding of the use of models to represent systems and validate system architectures. The student will gain proficiency in using a systems modeling language and shifting systems engineering from a document centric to a model centric paradigm. Prerequisites: Graduate Standing. (Co-listed with SYS ENG 6542).

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**COMP SCI 6200 Algorithmics II** (LEC 3.0)

Covers selected classical and recent developments in the design and analysis of algorithms, such as sophisticated data structures, amortized complexity, advanced graph theory, and network flow techniques. Prerequisite: A "C" or better grade in Comp Sci 5200.

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**COMP SCI 6201 Theory Of Computation** (LEC 3.0)

Turing machines and other machines. Godel numbering and unsolvability results. Machines with restricted memory access and limited computing time. Recursive functions, computable functionals and the classification of unsolvable problems. Prerequisite: A "C" or better grade in Comp Sci 2200.

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**COMP SCI 6202 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Sys Eng 6217 and Eng Mgt 6410).

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**COMP SCI 6203 Network Information Analysis** (LEC 3.0)

Modeling techniques and analytical methods to study the interaction of information and networks focusing on models and properties of network structures, and diffusion of information over networks. Expected outcomes are systematic inference of information encoded in network structures, and effective methods to disseminate or gather information from networks. Prerequisites: A "C" or better grade in Comp Sci 5200.

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**COMP SCI 6204 Applied Graph Theory for Computer Science** (LEC 3.0)

This course covers advanced concepts in graph theory and their applications. Graphs offer an excellent modeling and analysis tool for solving a wide variety of real-life problems. Emphasis will be on understanding concepts, theory, and proof techniques, and how to develop "cool" and "elegant" solutions for applications. Students will conduct projects. Prerequisite: A grade of "C" or better in Comp Sci 5200.

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**COMP SCI 6300 Object-Oriented Database Systems** (LEC 3.0)

This course will include a study of the origins of object-oriented database manipulation languages, their evolution, currently available systems, application to the management of data, problem solving using the technology, and future directions. Prerequisite: A "C" or better grade in Comp Sci 5102.

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**COMP SCI 6301 Web Data Management and XML** (LEC 3.0)

Management of semi-structured data models and XML, query languages such as Xquery, XML indexing, and mapping of XML data to other data models and vice-versa, XML views and schema management, advanced topics include change-detection, web mining and security of XML data. Prerequisite: A "C" or better grade in Comp Sci 5300.

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**COMP SCI 6302 Heterogeneous and Mobile Databases** (LEC 3.0)

This course extensively discusses multidatabase systems (MDBS) and mobile data access systems (MDAS). Moreover, it will study traditional distributed database issues within the framework of MDBSs and MDASs. Prerequisite: A "C" or better grade in Comp Sci 5300.

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**COMP SCI 6303 Pervasive Computing** (LEC 3.0)

Pervasive computing aims to seamlessly integrate computing with our everyday activities, so that people do not need to be aware of computing artifacts. This course will introduce various techniques needed to realize pervasive computing, such as position tracking and ad-hoc networking. Prerequisite: A grade of "C" or better in one of Comp Sci 4600, Comp Sci 5600, or Comp Eng 5410.

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**COMP SCI 6304 Cloud Computing and Big Data Management** (LEC 3.0)

Covers facets of cloud computing and big data management, including the study of the architecture of the cloud computing model with respect to virtualization, multi-tenancy, privacy, security, cloud data management and indexing, scheduling and cost analysis; it also includes programming models such as Hadoop and MapReduce, crowdsourcing, and data provenance. Prerequisites: A grade of 'C' or better in both COMP SCI 5800 and either COMP SCI 5300 or COMP SCI 5402.

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**COMP SCI 6400 Advanced Topics In Artificial Intelligence** (LEC 3.0)

Advanced topics of current interest in the field of artificial intelligence. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in one of Comp Sci 5400, Comp Sci 5401 or Comp Eng 5310.

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**COMP SCI 6401 Advanced Evolutionary Computing** (LEC 3.0)

Advanced topics in evolutionary algorithms, a class of stochastic, population-based algorithms inspired by natural evolution theory, capable of solving complex problems for which other techniques fail. Students will conduct challenging research projects involving advanced concept implementation, empirical studies, statistical analysis, and paper writing. Prerequisite: A "C" or better grade in Comp Sci 5401.

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**COMP SCI 6402 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 5001 Introduction to Data Mining. (Co-listed with Comp Eng 6302 and Sys Eng 6216).

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**COMP SCI 6404 Computer Graphics And Realistic Modeling** (LEC 3.0)

Algorithms, data structures, software design and strategies used to achieve realism in computer graphics of three-dimensional objects. Application of color, shading, texturing, antialiasing, solid modeling, hidden surface removal and image processing techniques. Prerequisite: A "C" or better grade in Comp Sci 5406.

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**COMP SCI 6405 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Sys Eng 6214 and Stat 6239).

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**COMP SCI 6406 Machine Learning in Computer Vision** (LEC 3.0)

Introduces machine learning fundamentals in current computer vision research. Topics include modeling complex data densities, regression and classification models, graphical models such as chains, trees, and grids, temporal models such as particle filtering and models for visual recognition such as deep learning. Students will implement select course topics. Prerequisite: A grade of "C" or better in either Comp Sci 5402 or Comp Sci 5404.

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**COMP SCI 6500 Theory Of Compiling** (LEC 3.0)

Properties of formal grammars and languages, language-preserving transformations, syntax-directed parsing, classes of parsing methods and the grammars for which they are suited, control flow analysis, and the theoretical framework of local and global program optimization methods. Prerequisite: A "C" or better grade in Comp Sci 5500.

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**COMP SCI 6600 Formal Methods in Computer Security** (LEC 3.0)

The course presents various vulnerabilities and threats to information in cyberspace and the principles and techniques for preventing and detecting threats, and recovering from attacks. The course deals with various formal models of advanced information flow security. A major project will relate theory to practice. Prerequisites: A grade of "C" or better in both Comp Sci 3600 and Comp Sci 5200.

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**COMP SCI 6601 Privacy Preserving Data Integration and Analysis** (LEC 3.0)

This course covers basic tools, in statistics and cryptography, commonly used to design privacy-preserving and secure protocols in a distributed environment as well as recent advances in the field of privacy-preserving data analysis, data sanitization and information retrieval. Prerequisite: A "C" or better grade in both Comp Sci 5300 and Comp Sci 3600.

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**COMP SCI 6602 Network Performance Analysis** (LEC 3.0)

Provides an introduction to performance modeling and analysis of computer networks. Topics include stochastic processes; performance measurement and monitoring; quantitative models for network performance, e.g., Markovian models for queues; simulation; and statistical analysis of experiments. Prerequisites: Comp Eng 5410 or Comp Sci 4600; Stat 3117 or 5643. (Co-listed with Comp Eng 6440).

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**COMP SCI 6603 Advanced Topics in Wireless Networks** (LEC 3.0)

Introduces the fundamentals and recent advances in wireless networking. Coverage includes cellular networks, wireless and mobile ad hoc networks, wireless mesh networks, sensor networks and wireless LANs with a focus on network operation. Special topics selected from the literature on wireless network security will also be addressed. Prerequisite: A "C" or better grade in Comp Sci 4600 or equivalent.

**COMP SCI 6604 Mobile And Sensor Data Management** (LEC 3.0)

Architectures of mobile computing systems; Mobile-IP support in mobile computing systems; location data management, Broadcasting and indexing, replication control; caching, fault tolerance and reliability of mobile systems; adhoc and sensor routing schemes, key management. Prerequisite: Comp Sci 4601.

**COMP SCI 6605 Advanced Network Security** (LEC 3.0)

Topics covered include network security issues such as authentication, anonymity, traceback, denial of service, confidentiality, forensics, etc. in wired and wireless networks. Students will have a clear, in-depth understanding of state of the art network security attacks and defenses. Prerequisite: A "C" or better grade in either Comp Eng 5420 or Comp Sci 4600.

**COMP SCI 6800 Distributed Systems Theory And Analysis** (LEC 3.0)

Analysis of the problems of state maintenance and correctness in concurrent computing systems using formal methods such as Hoare Logic, Temporal Logic, and Symbolic Model Checking. Prerequisite: A "C" or better grade in Comp Sci 5800.

**COMP SCI 6801 Topics in Parallel and Distributed Computing** (LEC 3.0)

Introduction of parallel and distributed computing fundamentals and advanced research topics. Students present research papers selected from the current literature on P&D computing paradigms. A term paper and oral presentation are required. Prerequisite: A "C" or better grade in Comp Sci 5802 or equivalent background. (Co-listed with Comp Eng 6110).

## Electrical Engineering (ELEC ENG)

**ELEC ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ELEC ENG 5001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ELEC ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**ELEC ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Civ Eng 5070).

**ELEC ENG 5099 Special Research And Thesis** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**ELEC ENG 5100 Advanced Electronic Circuits** (LEC 3.0)

Application of feedback theory, oscillators and frequency standards, precision analog techniques, low-power circuit design, interfacing sensors, designing for high reliability, electronics for harsh environments. Prerequisite: Elec Eng 3120.

**ELEC ENG 5120 Communication Circuits** (LEC 3.0)

Analysis and design of circuits used in communication systems. Topics include RF semiconductor devices, low-noise amplifiers, mixers, modulators, crystal oscillators, AGC circuits, highpower RF amplifiers, phase-locked loops, impedance matching, and frequency-selective networks and transformers. Prerequisites: Elec Eng 3120.

**ELEC ENG 5140 High-Frequency Amplifiers** (LEC 3.0)

Analysis and design of high frequency amplifiers. Topics include parameter conversions, activity and passivity, stability criteria, device operating conditions, Smith chart usage, matching networks, microstrip, scattering parameters, and practical applications. Prerequisites: Elec Eng 3120, 3600.

**ELEC ENG 5150 Photovoltaic Systems Engineering** (LEC 3.0)

Physics and characteristics of photovoltaic (solar) cell technologies, electronic control of alternative energy sources, site selection, array design, energy storage methods, electrical code compliance, stand-alone systems, grid-intertie systems, legal and economic considerations. Prerequisite: Senior or graduate standing in Science or Engineering.

**ELEC ENG 5160 Computer-Aided Network Design** (LEC 3.0)

Analysis and design of active and passive electric networks. Theory and computer application, including methods for automatic formulation of network state equations, network tolerance, network optimization, and device modeling. Prerequisites: Elec Eng 3100.

**ELEC ENG 5170 Introduction To Circuit Synthesis** (LEC 3.0)

Fundamentals of linear circuit theory. Matrix formulation, and topological methods as applied to circuit analysis. Properties of network functions and introductory network synthesis. Prerequisites: Elec Eng 3430.

**ELEC ENG 5200 Classical Optics** (LEC 3.0)

Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 2222 and Physics 2135 or 2111. (Co-listed with Physics 4503).

**ELEC ENG 5210 Fourier Optics** (LEC 3.0)

Applications of Fourier analysis and linear systems theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or Physics 4211. (Co-listed with PHYSICS 5503).

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**ELEC ENG 5220 Fiber And Integrated Optics** (LEC 3.0)

Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Physics 5513).

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**ELEC ENG 5250 Optical Computing** (LEC 3.0)

Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisite: Comp Eng 2210 or equivalent. (Co-listed with Comp Eng 5230).

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**ELEC ENG 5270 Smart Materials And Sensors** (LEC 2.0 and LAB 1.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5529, Mech Eng 5229 and Civ Eng 5118).

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**ELEC ENG 5300 Digital Control** (LEC 3.0)

Analysis and design of digital control systems. Review of ztransforms; root locus and frequency response methods; state space analysis and design techniques; controllability, observability and estimation. Examination of digital control algorithms. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5320 Neural Networks Control and Applications** (LEC 3.0)

Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of Control. Case studies and a term project. Prerequisites: Elec Eng 3320.

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**ELEC ENG 5325 Applied Nonlinear Control** (LEC 3.0)

Review of State Variable Models, Nonlinear Model and Phenomena, Lyapunov Stability, Phase Plane Analysis, Feedback Linearization, Sliding Mode and Backstepping Control, and Control Applications Prerequisite: Elec Eng 3320 or graduate standing.

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**ELEC ENG 5330 Fuzzy Logic Control** (LEC 3.0)

A mathematical introduction to the analysis, synthesis, and design of control systems using fuzzy sets and fuzzy logic. A study of the fundamentals of fuzzy sets, operations on these sets, and their geometrical interpretations. Methodologies to design fuzzy models and feedback controllers for dynamical systems. Various applications and case studies. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5340 Advanced PLC** (LAB 1.0 and LEC 2.0)

Advanced programmable logic controller (PLC) programming, function block, structured text, function chart, sequencer. Factory communications, system simulation, human-machine interface (HMI) programming. Advanced PID control. Network security and reliability. Class-wide project. Prerequisite: Elec Eng 3340.

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**ELEC ENG 5345 PLC Motion Control** (LEC 2.0 and LAB 1.0)

Factory automation motion control integrated with programmable logic controllers, servo control, variable-speed drive control, PackML state model, sizing motors and drives, machine safety, and experience with commercial hardware/software. Laboratory exercises on small-scale standard applications such as coordinated motion of multiple axes and camming. Prerequisite: Elec Eng 3340.

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**ELEC ENG 5350 Plantwide Process Control** (LEC 3.0)

Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: Chem Eng 4110 or Elec Eng 3320 or Elec Eng 3340 or graduate standing. (Co-listed with Chem Eng 5190).

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**ELEC ENG 5360 System Simulation And Identification** (LEC 3.0)

Computationally efficient methods of digital simulation of linear systems. Non-parametric identification. Parametric identification with least squares and recursive least squares algorithms. Algorithms programmed using MATLAB. Prerequisite: Elec Eng 3320.

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**ELEC ENG 5370 Introduction to Neural Networks and Applications** (LEC 3.0)

The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Sys Eng 5212).

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**ELEC ENG 5380 Autonomous Mobile Robots** (LEC 3.0)

This course will provide an introduction to mobile robots and current approaches to robot autonomy. Topics include mobile robot systems, modeling and control, sensors and estimation, localization and mapping, and motion planning. Prerequisites: Elec Eng 3320 or equivalent and Stat 3117 or equivalent.

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**ELEC ENG 5400 Digital Signal Processing II** (LEC 3.0)

Spectral representations, sampling, quantization, z-transforms, digital filters and discrete transforms including the Fast Fourier transform. Prerequisites: Elec Eng 3410.

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**ELEC ENG 5420 Communications Systems II** (LEC 3.0)

Random signals and their characterization; noise performance of amplitude, angle and pulse modulation systems; digital data transmission; use of coding for error control. Prerequisite: Elec Eng 3430.

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**ELEC ENG 5430 Wireless Networks** (LEC 2.0 and LAB 1.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Elec Eng 3430 or Comp Eng 3150. (Co-listed with Comp Eng 5430 and Sys Eng 5323).

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**ELEC ENG 5440 Stochastic Signal Analysis I** (LEC 3.0)

Introduction to the application of probabilistic models to typical electrical engineering problems. Topics include: methods for describing random voltages, random digital signals, correlation, linear mean-square estimation, linear transformation of random digital signals, and bit-error rate calculation for communication systems. Prerequisites: Math 3304 and Elec Eng 2120.

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**ELEC ENG 5450 Digital Image Processing** (LEC 3.0)

Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: Elec Eng 3430. (Co-listed with Comp Eng 5450).

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**ELEC ENG 5460 Machine Vision** (LEC 3.0)

Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: Elec Eng 3430. (Co-listed with Comp Eng 5460).

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**ELEC ENG 5500 Electric Drive Systems** (LEC 3.0)

Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Prerequisites: Elec Eng 3500 and Elec Eng 3320.

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**ELEC ENG 5510 Electric-Drive Vehicles** (LEC 3.0)

Course covers introductory topics related to understanding/analysis of electric, hybrid/plug-in hybrid power trains. Classification of hybrid drivetrains, driving cycles, energy storage systems, mechanical coupling devices, automotive applications of fuel cells and introduction to power converters. Prerequisite: Senior standing and Physics 2135.

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**ELEC ENG 5520 Power Electronics** (LEC 3.0)

Analysis, design, modeling, and control of switching mode power converter circuits for ac-dc, dc-dc, dc-ac, and ac-ac conversion. Power semiconductor devices, passive components, and non-ideal sources and loads. Applications to industry, consumer goods, electric vehicles, and alternative energy. Prerequisite: Elec Eng 3100.

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**ELEC ENG 5521 Power Electronics Laboratory** (LAB 2.0)

An introduction to power electronic circuits is presented. Students will construct several dc/dc, dc/ac and ac/dc converters. Various switching algorithms, including pulse width modulation, delta modulation, and hysteresis control will be developed to regulate and control the respective circuits. Prerequisite: Co-requisite Elec Eng 5520.

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**ELEC ENG 5540 Power Systems Engineering** (LEC 3.0)

Network analysis applied to power systems; the load flow concept; economic operation of power systems; synchronous machine reactances and transient stability; symmetrical components and asymmetrical faults; protective relaying. Prerequisite: Elec Eng 3540.

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**ELEC ENG 5550 Electric Power Quality** (LEC 3.0)

Definitions of power quality, types of power quality problems; sources of sags, transient overvoltages and harmonics; distribution overcurrent protection methods and their effect on power quality and reliability; harmonic analysis, principles of controlling harmonics, devices for filtering harmonics; power quality improvement methods. Prerequisite: Elec Eng 3500 or Elec Eng 3540.

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**ELEC ENG 5570 Extra High Voltage Engineering** (LEC 2.0 and LAB 1.0)

The physical phenomena associated with high voltage dielectric breakdown are presented. Methods of generating and measuring high voltages and currents are explained. Demonstration of design and performance. Field trips to companies for laboratory testing of high voltage according to industry standards will serve as the lab part of the course. Prerequisite: Senior standing.

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**ELEC ENG 5600 Interference Control in Electronic Systems** (LEC 3.0)

Principles of high frequency effects in PCBs and components, generation of unwanted radio-frequency (RF) signals by ICs, RF radiation mechanisms, shielding, and immunity against electrostatic discharge and RF signals. Prerequisites: Elec Eng 3430 and 3600.

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**ELEC ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design** (LEC 3.0)

Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Comp Eng 5620).

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**ELEC ENG 5630 Wave Propagation and Transmission Lines** (LEC 3.0)

The materials in this course are intended to provide a) follow up electromagnetics related courses, b) electromagnetics related career including RF design and c) a graduate degree in electromagnetic related fields an in-depth understanding of the basics of wave propagation and transmission lines. Prerequisite: Elec Eng 3600.

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**ELEC ENG 5640 Antennas and Propagation** (LEC 3.0)

Propagated fields of elemental dipole, directivity and gain, radiation resistance, the half-wave dipole, wire antennas, arrays, broadband antennas, aperture antennas, horn antennas, and antenna temperature. Prerequisite: Elec Eng 3600.

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**ELEC ENG 5650 Microwave and Millimeter Wave Engineering and Design** (LEC 3.0)

Introduce senior and graduate students to the concept of microwave and millimeter wave engineering and passive component design such as waveguide, cavities, couplers, detectors, mixers, etc., including network theory and scattering matrix. Finally, their specific application in the design of various microwave circuits will be discussed. Prerequisites: Elec Eng 3600.

**ELEC ENG 5660 Microwave Principles For Mixed-Signal Design** (LEC 3.0)

Transmission lines; coupled transmission lines; microwave network analysis; impedance matching and tuning; design of microwave amplifiers and oscillators. Prerequisite: Elec Eng 3600.

**ELEC ENG 5670 Nondestructive Testing** (LEC 3.0)

Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Met Eng 5510).

**ELEC ENG 5680 Introduction to Radar Systems** (LEC 3.0)

The objective of this course is to introduce senior and graduate students to various radar system principles, designs and applications (e.g., pulse, frequency-modulated, chirp, Doppler radars). Topics related to signals, systems, noise, resolution, multiple sampling, different imaging modalities, and remote sensing will also be discussed. Prerequisites: Elec Eng 3400 and Elec Eng 3600.

**ELEC ENG 5810 Computational Intelligence** (LEC 3.0)

Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Comp Eng 5310 and Sys Eng 5211).

**ELEC ENG 5870 Mechatronics** (LAB 1.0 and LEC 2.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Mech Eng 5478, Aero Eng 5478 and Comp Eng 5820).

**ELEC ENG 5880 Introduction to Robotics** (LEC 3.0)

This course provides an introduction to robotics, covering robot hardware, fundamental kinematics, trajectories, differential motion, robotic decision making, and an overview of current topics in robotics. Prerequisite: A grade of "C" or better in both Math 3108 and Comp Sci 1575. (Co-listed with Comp Sci 5403 and Comp Eng 5880).

**ELEC ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ELEC ENG 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ELEC ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**ELEC ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**ELEC ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**ELEC ENG 6099 Special Research And Thesis** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**ELEC ENG 6140 Advanced RF & Time Domain Measurements** (LAB 1.0 and LEC 2.0)

Advanced measurement techniques and instrumentation: Oscilloscopes (Real time and sampling, A/D conversion errors, Probing, Jitter, Noise), Spectrum analyzer (concepts, applications), Network Analyzer (concepts, calibration), Impedance measurements. Lab experiments are a main part of this class. Prerequisite: Graduate standing.

**ELEC ENG 6150 Signal Integrity, High Speed Digital and RF Design Laboratory** (LAB 3.0)

This is an RF and digital electronics design class. Student groups will design, manufacture and test RF and/or digital circuits during the class. Besides this project work the lecture part will emphasize circuit design, layout, parasitic effects and design for testability. Prerequisite: Elec Eng 3600.

**ELEC ENG 6200 Electromagnetic Optics** (LEC 3.0)

Propagation, control, and modulation of laser radiation. Topics include optical polarization, interference, layered and anisotropic media, electro-optic devices, acousto-optic devices, and nonlinear optics. Prerequisite: Elec Eng 3600 or Physics 4211.



**ELEC ENG 6240 Semiconductor Devices** (LEC 3.0)

Properties of semiconductors, junctions and transistors; high frequency and high-current effects; recombination processes; field-effect devices, semiconductor devices and microcircuits. Prerequisite: Graduate status in Elec Eng.

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**ELEC ENG 6260 Integrated Microsystems Engineering** (LEC 1.5 and LAB 1.5)

Theory and practice of multidisciplinary integrated microsystem technologies. The topics include (1) micromachining technology, (2) review of mechanical, optical, microfluidic and (bio) chemical microsensors and microactuators, (3) hands-on lab session for design, fabrication, and characterization of microsystems. Prerequisite: Graduate standing.

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**ELEC ENG 6290 Advanced Topics in Optics and Devices** (LEC 3.0)

Advanced topics of current interest in optics and devices. Selected topics include semiconductor materials, electronic devices, wave-based sensing, fiber optic systems, optoelectronics, and photonic engineering. Prerequisite: Graduate Standing.

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**ELEC ENG 6300 Linear Control Systems** (LEC 3.0)

Review of linear algebra, state variable formulations, solutions of state equations; controllability and observability; multivariable systems, matrix-fraction decompositions; design of state and output feedback controllers and observers; introduction to calculus of variations; linear quadratic regulators. Prerequisite: Elec Eng 3320.

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**ELEC ENG 6310 Optimal Control And Estimation** (LEC 3.0)

Review of linear quadratic regulators (LQR), LQR extensions; constrained optimization (Pontragin's minimum principle); review of probability theory and random processes; optimal prediction and filters; frequency domain properties of LQR and Kalman filters; linear quadratic Gaussian (LQG) control; model uncertainties, frequency shaping, LQG/LTR design methodology. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6320 Nonlinear Control Systems** (LEC 3.0)

Numerical solution methods, describing function analysis, direct and indirect methods of Liapunov stability, applications to the Lure problem - Popov circle criterion. Applications to system design and feedback linearizations. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6330 Robust Control Systems** (LEC 3.0)

Performance and robustness of multivariable systems, linear fractional transformations, LQG/LTR advanced loop shaping, Youla parameterization,  $H_\infty$  optimal control, mixed  $H_2$  and  $H_\infty$  control, controller synthesis for multiple objective optimal control, linear matrix inequalities theory and case studies. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6335 Discrete-Time Neural Network Control** (LEC 3.0)

Neural network topologies, universal function approximation property, background on Lyapunov stability & dynamic systems, control of a class of nonlinear systems using single and multilayer neural networks, feedback linearization, strict & nonstrict feedback systems, MIMO system, system identification, output feedback control, and hardware implementation. Prerequisites: Elec Eng 6300.

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**ELEC ENG 6350 Neural Network Control of Nonlinear Continuous-time Systems** (LEC 3.0)

Neural network topologies, universal function approximation property, background on Lyapunov stability and dynamic systems, control of a class of nonlinear systems and robot manipulators, feedback linearization, backstepping control, force control, neural observers, decentralized neural network control, neural network-based optimal control and applications. Prerequisite: Elec Eng 6300.

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**ELEC ENG 6360 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

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**ELEC ENG 6370 Adaptive Control** (LEC 3.0)

Intro to adaptive control, Lyapunov stability, positive real and strictly positive real, Kalman-Yukabovich lemma, system identification, direct/indirect adaptive control, adaptive observers, adaptive control design, nonlinear adaptive design tools-adaptive control with multiple models, adaptive neural network control, decentralized adaptive control design. Prerequisites: Elec Eng 6300.

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**ELEC ENG 6390 Current Topics In Control Theory** (LEC 3.0)

Topics of current interest in control theory literature. Offered as interest and demand warrant. Prerequisite: Consent of instructor.

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**ELEC ENG 6400 Advanced Digital Signal Processing** (LEC 3.0)

Continuation of Elec Eng 5400. Effects of discrete noise sources in digital signal processing; discrete spectral analysis of random signals; discrete time signal detection, estimation, and filtering algorithms. Prerequisites: Elec Eng 5400 or Elec Eng 5420; Elec Eng 5440 or Stat 5643.

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**ELEC ENG 6410 Information Theory And Coding** (LEC 3.0)

Principles of information generation, transmission and processing; quantitative measure of information, entropy source encoding; channels; mutual information; channel capacity; Shannon's second theorem for discrete channels; introduction to coding for error controls; continuous information sources. Prerequisites: Elec Eng 5420 or Elec Eng 5440 or Stat 5643.

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**ELEC ENG 6420 Wireless Communications** (LEC 3.0)

Introduction to the principle of wireless communication systems. Topics include: wireless channel characteristics, cellular concepts, channel capacity analysis, transceiver architectures, diversity techniques, multiple access schemes, and practical wireless systems. Prerequisite: Elec Eng 5420 or Elec Eng 5440 or equivalent.

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**ELEC ENG 6430 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Sys Eng 6324).

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**ELEC ENG 6440 Stochastic Signal Analysis II** (LEC 3.0)

Continuous-time stochastic signals, multi-dimensional signals, Wiener and matched filters, LMS equalization, non-linear systems with random inputs, spectral estimation and Markov chains. Prerequisites: Stat 5643 or Elec Eng 5440.

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**ELEC ENG 6450 Statistical Decision Theory** (LEC 3.0)

Classical detection and estimation theory with applications; hypothesis testing, detection of known signals, matched filter receiver implementation, detection of signals with unknown parameters, sequential and nonparametric detection, detection of stochastic signals: Parameter estimation theory with application to modulation. Prerequisite: Elec Eng 5440.

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**ELEC ENG 6490 Advanced Topics In Communications** (LEC 3.0)

Advanced topics of current interest in communications and signal processing such as spread spectrum, digital processing of communications, speech, and radar signals, applications of pattern recognition, communications networks, specialized coding topics. Repeatable for additional credit toward degree each time a different subtitle offered. Prerequisite: Elec Eng 5420 or 5440.

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**ELEC ENG 6500 Advanced Theory Of Electric Machines** (LEC 3.0)

Energy conversion, reference frame theory, transient and dynamic modeling of ac machines, simulation of ac machines, parameter identification, model-order reduction, advanced topics depending on semester taught. Prerequisite: Elec Eng 3500.

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**ELEC ENG 6510 Advanced Electric Drive Vehicles** (LEC 3.0)

This course covers an entire range of advanced topics related to the analysis, design, control, simulation, and optimization of electric, hybrid, and plug-in hybrid power-trains including the automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Prerequisite: Elec Eng 5500 or Elec Eng 5520.

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**ELEC ENG 6520 Advanced Power Electronics** (LEC 3.0)

The purpose of this course is to cover selected areas of power electronics in greater depth. The topics covered include small signal analysis of power converters, voltage- and current- mode control, soft switching techniques, power factor correctors, multi-level converters, and PWM techniques. Prerequisite: Elec Eng 5520.

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**ELEC ENG 6525 Power Converter Modeling and Design** (LEC 3.0)

Students will integrate electrical, magnetic, and thermal modeling techniques into a design process for switching power converters. A variety of applications will be considered, including dc-dc, ac-dc, and dc-ac converters over a wide power range. Prerequisite: Elec Eng 5520.

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**ELEC ENG 6530 Power System Reliability** (LEC 3.0)

Reliability definition and measures. Probability concepts and Markov chains. Failure models and availability models. Generator system reliability. Loss of load probability method. Evaluation of transmission network reliability. Analysis of the electric power system reliability. Prerequisite: Stat 5643 or Elec Eng 5420.

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**ELEC ENG 6540 Computer Methods In Power System Analysis** (LEC 3.0)

Algorithms for large scale system solution, non-linear systems, ordinary differential equations, eigenvalue problems, modal information, and optimization. Applications to power systems analysis. Prerequisite: Elec Eng 3540 or similar course.

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**ELEC ENG 6550 Power System Stability** (LEC 3.0)

Synchronous machine theory and modelling; AC transmission; power system loads; excitation systems; control of active and reactive power; small signal stability; transient stability; voltage stability; mid-term and long-term stability; subsynchronous oscillations; stability improvement. Prerequisite: Elec Eng 3540 or similar course.

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**ELEC ENG 6560 Power System Protection** (LEC 3.0)

Protective relaying incorporating electromechanical, solid state and computer relaying methods for high voltage transmission systems; instrument transformers; generator, transformer, line and bus protection; effect of system grounding; pilot protection and out of step relaying principles. Prerequisite: Elec Eng 5560 and 5540.

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**ELEC ENG 6565 Power System Protection II** (LEC 3.0)

Protective relaying advanced topics focusing on methods for generation and high voltage transmission systems; generator, motor, transformer, transmission line and bus protection; pilot protection and out of step relaying principles; and NERCPRC (Protective Relay and Control) reliability standard requirements. Prerequisite: Elec Eng 6560.

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**ELEC ENG 6570 Surge Phenomena In Power Systems** (LEC 3.0)

Study of transmission system insulation, distributed constant lines, terminations, multiple reflections, lightning performance, characteristics of sustained and switching overvoltages, surge voltages due to system faults, energizing and reclosing of circuit breakers. Methods of reducing overvoltages to acceptable levels. Prerequisite: Elec Eng 5540.

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**ELEC ENG 6580 Power System Operations** (LEC 3.0)

Optimal dispatch operations, economic loading of power plants, mathematical optimization, locational marginal pricing, optimal power flow; effect of hydro and wind power plants on system economics; contingency analysis and system security, state estimation. Prerequisite: Elec Eng 5540.

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**ELEC ENG 6600 Advanced Electromagnetics I** (LEC 3.0)

Review of Maxwell's equations, constitutive relations, and boundary conditions. Wave propagation and polarization. Vector magnetic and electric potentials. Equivalent representations of fields, Babinet's principle. Circular waveguides. Green's functions. Prerequisite: Elec Eng 3600 or equivalent undergraduate electromagnetics course.

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**ELEC ENG 6610 Electromagnetic Waves II** (LEC 3.0)

Circular waveguides, circular cavities, scattering by cylinders, apertures in cylinders, spherical cavities, orthogonality relationships, source of spherical waves, scattering by spheres, perturbational and variational techniques, microwave networks, probes in cavities, and aperture coupling to cavities. Prerequisite: Elec Eng 6600.

**ELEC ENG 6630 Computational Electromagnetics** (LEC 3.0)

Differential-equation based numerical methods-finite element, finite-difference, and finite-difference time-domain-for solving static and dynamic equations of electromagnetics. Applications considered are multi-conductor transmission lines, Maxwell's equations for radiation and scattering, and electric machinery. Prerequisite: Elec Eng 3600.

**ELEC ENG 6640 Advanced Topics in Antenna Analysis and Design** (LEC 3.0)

Introduction and discussion of advanced antenna design issues including: polarization, antenna synthesis and source modeling, broadband antennas, aperture and microstrip antenna simulation and design, and antenna pattern measurement techniques including near-field to far-field transformation. Prerequisite: Elec Eng 5640 or equivalent.

**ELEC ENG 6830 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Sys Eng 6214, Comp Sci 6405 and Stat 6239).

## Engineering Management (ENG MGT)

**ENG MGT 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ENG MGT 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ENG MGT 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Env Eng 5070, Comp Eng 5070, Elec Eng 5070, Civ Eng 5070).

**ENG MGT 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**ENG MGT 5110 Managerial Decision Making** (LEC 3.0)

Individual and group decision making processes and principles for engineers and technical managers with emphasis on the limitations of human rationality and the roles of social influence and organizational contexts; principles and skills of negotiation. Prerequisite: Senior or graduate standing.

**ENG MGT 5111 Management for Engineers and Scientists** (LEC 3.0)

The transition of the engineer or scientist to manager; study of management roles and theory, organizational systems and behavior, managing and motivating technical personnel, leadership, communication, processes, and customer focus. Prerequisite: Graduate standing.

**ENG MGT 5210 Economic Decision Analysis** (LEC 3.0)

Comprehensive treatment of engineering economy including effects of taxation and inflation; sensitivity analysis; decisions with risk and uncertainty; decision trees and expected value, normally includes solutions on personal computer and student problem report. Prerequisite: Graduate students without previous course in engineering economy because of partial overlap.

**ENG MGT 5212 Intelligent Investing** (LEC 3.0)

An overview of the essential elements of intelligent investing. Coverage includes stocks, bonds, exchange traded funds, mutual funds, stock screening, fundamental and technical analysis, valuation, market and industry analysis, macroeconomic indicators, investing strategies, and portfolio construction. Prerequisites: Senior or Graduate Standing.

**ENG MGT 5312 Advanced Risk Assessment and Reduction** (LEC 3.0)

Safe, secure manufacturing facilities protect the health of employees and the public, preserve the environment, and increase profitability. Methods for systematically identifying hazards and estimating risk improve the safety performance and security of manufacturing facilities. Prerequisite: Senior or Graduate Standing.

**ENG MGT 5313 Packaging Management** (LEC 3.0)

Provides a comprehensive background in the field of packaging and its place in productive systems. Emphasizes the design or economics of the system. Analyzes the management of the packaging function and interrelationship with other functions of an enterprise.

**ENG MGT 5315 Interdisciplinary Problems In Manufacturing Automation** (LEC 1.0 and LAB 2.0)

Introduction to basic techniques and skills for concurrent engineering, manufacturing strategies, product design, process planning, manufacturing data management and communication are the topics covered. Students experiment the design process through team projects and structured manufacturing laboratory work. (Co-listed with Mech Eng 5644, Chem Eng 4310).

**ENG MGT 5316 Safety Engineering Management** (LEC 3.0)

This course is an introduction to the principles of safety engineering applied to industrial situations. Job safety analysis, reduction of accident rates, protective equipment, safety rules and regulations, environmental hazards, health hazards, and ergonomic hazards are covered. Prerequisite: Senior or graduate standing.

**ENG MGT 5320 Project Management** (LEC 3.0)

Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisite: Graduate Standing. (Co-listed Sys Eng 5105).

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**ENG MGT 5330 Advanced Human Factors** (LEC 3.0)

An in-depth review of the foundations of human factors, focusing on the interaction of people with various forms of technology in a variety of environments. Topics include research and evaluation methods, displays (e.g., visual, auditory), attention and information processing, decision making, motor skills, anthropometry, and biomechanics. (Co-listed with PSYCH 5710).

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**ENG MGT 5410 Industrial System Simulation** (LEC 3.0)

Simulation modeling of manufacturing and service operations through the use of computer software for operational analysis and decision making. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5411 Engineering Design Optimization** (LEC 3.0)

This course is an introduction to the theory and practice of optimal design as an element of the engineering design process. The use of optimization as a tool in the various stages of product realization and management of engineering and manufacturing activities is stressed. The course stresses the application of nonlinear programming methods. Prerequisite: Math 3304 or 3329.

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**ENG MGT 5412 Operations Management Science** (LEC 3.0)

Application of management science with an emphasis on supporting managerial decision-making. Design and operations of systems are modeled and analyzed using quantitative and qualitative techniques implemented using modern technology. Specific approaches include mathematical modeling and optimization, probabilistic/statistical analysis, and simulation. Prerequisites: Graduate standing.

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**ENG MGT 5414 Introduction To Operations Research** (LEC 3.0)

Mathematical methods for modeling and analyzing industrial systems, topics including linear programming, transportation models, and network models. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5510 Industrial Marketing Systems Analysis** (LEC 3.0)

An analysis of the factors of engineered products, customers, communication, promotion, personal selling, persuasion and management within a dynamic industrial sales environment. Prerequisites: Senior or graduate standing.

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**ENG MGT 5511 Technical Entrepreneurship** (LEC 3.0)

Student teams develop a complete business plan for a company to develop, manufacture and distribute real technical/product service. Lectures & business fundamentals, patents, market/ technical forecasting, legal and tax aspects, venture capital, etc., by instructor and successful technical entrepreneurs. Prerequisite: Senior or graduate standing.

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**ENG MGT 5512 Legal Environment** (LEC 3.0)

Study of the effect of the legal environment on the decisions which the engineering manager must make. The course investigates the social forces that produced this environment and the responsibilities incumbent upon the engineer. Prerequisites: Senior or graduate standing.

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**ENG MGT 5513 Energy and Sustainability Management Engineering** (LEC 3.0)

This course explores strategic processes and partnership required for the management of sustainable energy infrastructures and innovation in energy systems. Topics relate to renewable energy, energy efficiencies, energy conversion, energy technology, and economic efficiency of energy sources. Prerequisite: Senior or Graduate Standing.

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**ENG MGT 5514 Patent Law** (LEC 3.0)

A presentation of the relationship between patent law and technology for students involved with developing and protecting new technology or pursuing a career in patent law. Course includes an intense study of patentability and preparation and prosecution of patent applications. Prerequisite: Senior or graduate standing.

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**ENG MGT 5515 Integrated Product And Process Design** (LEC 3.0)

Emphasize design policies of concurrent engineering and teamwork, and documenting of design process knowledge. Integration of product realization activities covering important aspects of a product life cycle such as "customer" needs analysis, concept generation, concept selection, product modeling, process development, and end of product life options. Prerequisites: Junior or above standing. (Co-listed with MECH ENG 5757).

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**ENG MGT 5516 Integrated Product Development** (LEC 1.0 and LAB 2.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, process quality, cost, supply chain management, and product support. Students will produce a final engineering product at the end of the project. Prerequisite: Eng Mgt 5515 or Mech Eng 5757 or Mech Eng 3653 or Mech Eng 5708. (Co-listed with Mech Eng 5758).

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**ENG MGT 5610 Advanced Facilities Planning & Design** (LAB 1.0 and LEC 2.0)

An integrated approach to the planning and design of facilities; examination of advanced techniques and tools for facility location, space allocation, facility layout materials handling system design, work place design; e.g. mathematical programming and simulation modeling. Prerequisites: Graduate standing.

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**ENG MGT 5613 Value Analysis** (LEC 3.0)

An organized effort at analyzing the function of goods or services for the purpose of achieving the basic functions at the lowest overall cost, consistent with achieving the essential characteristics. Covers the basic philosophy, function analysis, FAST diagramming, creativity techniques, evaluation of alternatives, criteria analysis, and value stream mapping. Prerequisite: Senior or graduate standing.

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**ENG MGT 5614 Supply Chain Management Systems** (LEC 3.0)

This course focuses on the development of logistics management skills related to global supply chains. Particular attention will be given to supply chain systems management as part of the firm's strategic positioning, cultural interactions and transportation sourcing decisions. Prerequisite: Stat 3115 or Stat 3117.

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**ENG MGT 5615 Production Planning And Scheduling** (LEC 3.0)

Introduction to basic techniques of scheduling, manufacturing planning and control, just-in-time systems, capacity management, master production scheduling, single machine processing, constructive Algorithms for flow-shops, scheduling heuristics, intelligent scheduling systems are the topics covered. Prerequisite: Eng Mgt 3310.

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**ENG MGT 5710 Six Sigma** (LEC 3.0)

This course is an introduction to the principles of implementing the Six Sigma philosophy and methodology. Topics include tools and methods including process flow diagrams, cause and effect diagrams, failure mode and effects analysis, gage R&R, capability studies, design of experiments and strategy for organizing six sigma techniques in industry. Prerequisite: Graduate standing.

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**ENG MGT 5711 Total Quality Management** (LEC 3.0)

Examination of various quality assurance concepts and their integration into a comprehensive quality management system: statistical techniques, FMEA's, design reviews, reliability, vendor qualification, quality audits, customer relations, information systems, organizational relationships, motivation. Prerequisite: Senior or graduate standing.

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**ENG MGT 5712 Introduction To Quality Engineering** (LEC 3.0)

This course is an introduction to the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered in-depth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Other contributions in the field are also considered. Prerequisite: Eng Mgt 5711.

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**ENG MGT 5713 Management And Methods In Reliability** (LEC 3.0)

Study of basic concepts in reliability as they apply to the efficient operation of industrial systems. Prerequisite: Stat 3115, 3117, or 5643.

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**ENG MGT 5714 Statistical Process Control** (LEC 3.0)

The theoretical basis of statistical process control procedures is studied. Quantitative aspects of SPC implementation are introduced in context along with a review of Deming's principles of quality improvement and a brief introduction to sampling inspection. Prerequisite: Stat 3115, or Stat 3117.

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**ENG MGT 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**ENG MGT 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENG MGT 6010 Seminar** (IND 0.0-6.0)

Discussion of current topics.

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**ENG MGT 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/ comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**ENG MGT 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**ENG MGT 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**ENG MGT 6101 Advanced Research Methodology in Engineering Management** (LEC 3.0)

An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing. (Co-listed with Sys Eng 6101).

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**ENG MGT 6110 Case Studies In General Management** (LEC 3.0)

A quantitative study of engineering management problems related to the functioning of the industrial enterprise through case studies. Prerequisite: Preceded or accompanied by an Eng Mgt 6000 level course.

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**ENG MGT 6112 Leadership for Engineers** (LEC 3.0)

Provides engineers with a background in leadership concepts and principles; enables students to develop practical skills in leading and managing through multiple personal assessment. Topics include leadership styles, managing commitments, conflict resolution, change management, emotional intelligence, team dynamics and business ethics. Prerequisite: Eng Mgt 5110.

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**ENG MGT 6113 Advanced Personnel Management** (LEC 3.0)

Current practices of procurement and maintenance of technical personnel in research, development, and design organizations. Adaptation of such personnel to the technological enterprise, current practices in personnel administration, labor management relationships.

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**ENG MGT 6211 Advanced Financial Management** (LEC 3.0)

Principles of financial organization and management in the technological enterprise; demands for funds; internal and external supply of funds; budgetary control; reserve and dividends policy. Emphasizes systems approach and problems of engineering design and automation as they influence financial decisions. Prerequisite: Eng Mgt 1210 or 5210.

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**ENG MGT 6212 Investment** (LEC 3.0)

An introduction to the theory and practice of investment, including financial markets and instruments, security trading, mutual funds, investment banking, interest rates, risk premiums, the capital asset pricing model, arbitrage pricing theory, market efficiency, bonds and the fixed income market, equity valuation, fundamental and technical analysis. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6612).

**ENG MGT 6213 Financial Engineering** (LEC 3.0)

An introduction to financial engineering, with an emphasis on financial derivatives, including the future markets, the pricing of forwards and futures, forward rate agreements, interest and exchange rate futures, swaps, the options markets, option strategies, the binomial and Black-Scholes models for option valuation, the option Greeks, and volatility smiles. Prerequisites: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6613).

**ENG MGT 6214 Financial Engineering II** (LEC 3.0)

This course introduces advanced topics in financial engineering, which includes introduction to Wiener processes, martingales and Ito's lemma; basic numerical methods for options pricing, exotic options; interest rate models; stochastic volatility models and jump-diffusion models; and value-at-risk. Prerequisite: Eng Mgt 6213/Sys Eng 6613. (Co-listed with Sys Eng 6614).

**ENG MGT 6215 Financial Risk Management** (LEC 3.0)

Techniques and methods for managing financial risk, including portfolio theory, Monte Carlo methods, ARIMA, time series forecasting, Value-at-Risk, stress testing, extreme value theory, GARCH and volatility estimation, random variables and probability distributions, real options, decision trees, utility theory, statistical decision techniques, and game theory. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Sys Eng 6615).

**ENG MGT 6310 Human Systems Integration** (LEC 3.0)

This course considers Human Systems Integration (HSI) in a variety of applications including systems acquisition and training, HSI tools, techniques, and procedures. Prerequisite: Eng Mgt 4330 or Psych 4710.

**ENG MGT 6322 Case Studies in Project Management** (LEC 3.0)

Includes the main components of the Project Management Institute (PMI) Body of Knowledge; case studies in project management including project implementation, organizational structures, project estimating, project scheduling, project risk management, and conflict management. Prerequisite: Eng Mgt 5320 or equivalent.

**ENG MGT 6323 Global Project Management** (LEC 3.0)

In depth and advanced topics in project management including project management methodologies, strategic planning for excellence, project portfolio management, integrated processes, culture, and behavioral excellence; normally includes a hands-on group project. Prerequisite: Eng Mgt 5320 or equivalent.

**ENG MGT 6410 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Sys Eng 6217 and Comp Sci 6202).

**ENG MGT 6411 Advanced Topics in Simulation Modeling** (LEC 3.0)

Design and analysis of distributed systems using discrete-event simulations and synchronization of distributed models. Design and implementation of finite state automata and simulation models as control execution systems. Functioning of real-time, agent-based, and multipass simulations. Prerequisite: Eng Mgt 5410 or Graduate standing.

**ENG MGT 6412 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Math 6665 and Sys Eng 6412).

**ENG MGT 6413 Advanced Engineering Management Science** (LEC 3.0)

Solving of managerial problems utilizing management science techniques. Problems are analyzed, modeled and solved using such techniques as linear, goal, dynamic, programming, simulation, statistical analysis or other non-linear methods. Solutions will involve the use of personal or mainframe computers. A study of the current literature in management science will also be conducted. Prerequisite: Eng Mgt 5414 or graduate standing.

**ENG MGT 6415 Optimization under Uncertainty** (LEC 3.0)

Optimization in the presence of model uncertainty or system stochasticity is discussed. The course covers fundamentals of stochastic programming, robust optimization, and dynamic programming. Prerequisites: Graduate standing. (Co-listed with Sys Eng 6110).

**ENG MGT 6510 Technological Innovation Management** (LEC 3.0)

Technological innovation is new technology creating new products and services. This course studies the issues of managing technological innovation under four topics: 1) Innovation; 2) New Ventures; 3) Corporate Research & 4) R&D Infrastructure. Prerequisite: Eng Mgt 5111.

**ENG MGT 6511 Advanced Marketing Management** (LEC 3.0)

Study of marketing decision areas in the technically based firm, including product selection and development, marketing research, market development, distribution, advertising, and promotion. Pricing policies including legal aspects and problems in selecting, training and controlling field sales force. Examination of interaction within consumer and industrial marketing environments. Prerequisites: Eng Mgt 5111, Econ 1200.

**ENG MGT 6610 Advanced Production Management** (LEC 3.0)

Examination of responsibilities of production manager in the technological enterprise for providing finished goods to meet the quality, price, quantity and specification needs of the market place. Study of functions of production manager. Quantitative approach to decision making in production management. Prerequisites: Senior or graduate standing and advanced mathematical modelling competence.

**ENG MGT 6611 Lean Systems** (LEC 3.0)

Lean Systems embodies a total enterprise philosophy built on removing waste. Concepts such as flow, just-in-time, lead times, inventory turns, standardized work, pull system, value streams, quick changeover, workplace organization, and visual controls are discussed to improve system performance. Prerequisite: Graduate standing.

**ENG MGT 6710 Design for Six Sigma** (LEC 3.0)

Principles of Design for Six Sigma for product development. Topics include tools and methods including quality function deployment, concept generation, concept selection, product modeling, process development, DFX strategies, failure mode and effects analysis, design of experiments, TRIZ, and robust design. Prerequisite: Eng Mgt 5710.

**ENG MGT 6711 Quality Engineering** (LEC 3.0)

This course is an examination of the theory and practice of quality engineering with particular emphasis on the work of Genichi Taguchi. The application of the quality loss function, signal to noise ratio and orthogonal arrays is considered in depth for generic technology development; system, product and tolerance design; and manufacturing process design. The emphasis of the course is off-line quality control. Prerequisites: Eng Mgt 5711 and Math 3329 or equivalent.

**ENG MGT 6713 Tolerance Design** (LEC 3.0)

This course is an examination of the theory and practice of allowance allocation for high quality and low cost manufacture of mass-produced consumer products, including technology intensive products, such as automobiles, trucks, military and commercial airplanes, computers and consumer electronics. Prerequisite: Eng Mgt 5711 or equivalent.

## Environmental Engineering (ENV ENG)

**ENV ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department.

**ENV ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ENV ENG 5070 Teaching Engineering** (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Comp Eng 5070, Elec Eng 5070, Civ Eng 5070).

**ENV ENG 5360 Water Resources And Wastewater Engineering** (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Civ Eng 5360).

**ENV ENG 5605 Environmental Systems Modeling** (LEC 3.0)

Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Civ Eng 5605).

**ENV ENG 5619 Environmental Engineering Design** (LAB 1.0 and LEC 2.0)

Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Civ Eng 5619).

**ENV ENG 5630 Remediation of Contaminated Groundwater And Soil** (LEC 2.0 and LAB 1.0)

Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Civ Eng 5630).

**ENV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design** (LEC 3.0)

Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisite: Env Eng 3615 or Civ Eng 3615 or graduate standing. (Co-list with Civ Eng 5635).

**ENV ENG 5640 Environmental Law And Regulations** (LEC 3.0)

This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, and CERCLA. Case studies will be emphasized. (Co-listed with Civ Eng 5640).

**ENV ENG 5642 Sustainability, Population, Energy, Water, and Materials** (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Civ Eng 5642 and Arch Eng 5642).

**ENV ENG 5650 Public Health Engineering** (LEC 3.0)

A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with grade of "C" or better. (Co-listed with Civ Eng 5650).

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**ENV ENG 5660 Introduction To Air Pollution** (LEC 3.0)

Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5660).

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**ENV ENG 5662 Air Pollution Control Methods** (LEC 3.0)

Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5662).

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**ENV ENG 5665 Indoor Air Pollution** (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Civ Eng 5665 and Arch Eng 5665).

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**ENV ENG 5670 Solid Waste Management** (LEC 3.0)

A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Civ Eng 5670).

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**ENV ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

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**ENV ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**ENV ENG 6010 Seminar** (IND 0.0)

Discussion of current topics.

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**ENV ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**ENV ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of instructor.

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**ENV ENG 6600 Chemical Principles In Environmental Engineering** (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Civ Eng 6600).

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**ENV ENG 6601 Biological Principles In Environmental Engineering Systems** (LAB 1.0 and LEC 2.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Civ Eng 6601).

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**ENV ENG 6602 Environmental Chemistry** (LEC 2.0 and LAB 1.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Civ Eng 6602).

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**ENV ENG 6608 Environmental Engineering Analysis Laboratory** (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Civ Eng 6608).

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**ENV ENG 6611 Physicochemical Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6611 and Chem Eng 6330).

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**ENV ENG 6612 Biological Operations In Environmental Engineering Systems** (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion process. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6612).

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**ENV ENG 6671 Industrial And Hazardous Waste Treatment** (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Civ Eng 6671).

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## Explosives Engineering (EXP ENG)

### **EXP ENG 5000 Special Problems** (IND 1.0-3.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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### **EXP ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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### **EXP ENG 5112 Explosives Handling and Safety** (LEC 3.0)

Basic handling & safety for explosives, explosive devices and ordnance related to laboratory handling, testing, manufacturing & storage, for both civil and defense applications. Classroom instruction only. Prerequisite: Junior Standing or above.

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### **EXP ENG 5512 Commercial Pyrotechnics Operations** (LAB 1.0 and LEC 2.0)

Provide participants with training preparing for Missouri Licensed Display Operator (Outdoor) License and advanced lead pyrotechnic operator training. Class work will be complemented by practical training in laboratory sessions, culminating in a full pyrotechnic show, from start to finish. Prerequisites: Both Chem 1310 and Chem 1319 or their equivalent; US Citizen or permanent resident, Successful background check, resident enrollment at Missouri S&T.

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### **EXP ENG 5513 Stage Pyrotechnics and Special Effects** (LAB 2.0 and LEC 1.0)

Use of energetic materials in close proximity to audiences. Provide participants with training preparing for Missouri Pyrotechnics Display Operators License. Covers: close proximity indoor and outdoor pyrotechnics and special effects. Working with stage crews and talent, safety and permitting. Prerequisites: Both Chem 1310 and Chem 1319 or their equivalent; US Citizen or permanent resident, Successful background check, resident enrollment at Missouri S&T.

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### **EXP ENG 5514 Display Fireworks Manufacturing** (LEC 1.0 and LAB 2.0)

Theory and practice of manufacturing display fireworks. Focusing on safety, chemical interaction, color development, basic theory, state and federal law. The lab will include hands on building of ball and canister shells and other pyrotechnic effects. Prerequisites: Chem 1310, Chem 1319, Chem 1100; one of Econ 1100, Econ 1200, Eng Mgt 1210; Successful background check.

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### **EXP ENG 5555 Computer Fired Pyrotechnic Show Design and Firing System Operation** (LAB 2.0 and LEC 1.0)

Students will learn to use music editing, electronic firing system operation and Fire One pyrotechnic choreography and simulation software to design their own pyromusical show programs. Creation of a musical sound track, selecting the fireworks and choreographing to the musical score. Create, setup, diagnose and fire a pyrotechnic show. Prerequisites: Exp Eng 5512 or Exp Eng 5513 and successful background check.

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### **EXP ENG 5612 Principles of Explosives Engineering** (LEC 2.0 and LAB 1.0)

Theory and application of explosives in the mining industry; explosives, initiating systems, characteristics of explosive reactions and rock breakage, fundamentals of blast design, drilling and blasting, regulatory and safety considerations. Prerequisites: Min Eng 2126; successful background check. (Co-listed with Min Eng 5612).

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### **EXP ENG 5622 Blasting Design And Technology** (LAB 1.0 and LEC 2.0)

Advanced theory and application of explosives in excavation; detailed underground blast design; specialized blasting including blast casting, construction and pre-splitting. Introduction to blasting research. Examination of field applications. Prerequisites: Min Eng 5612. Student must be at least 21 years of age. Successful background check. (Co-listed with Min Eng 5622).

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### **EXP ENG 5711 Explosives in Industry** (LEC 3.0)

Overview of how explosives are applied in various industrial settings. Focus is placed on the general application, identification, and necessity of explosives in industry. Topics include explosive use in surface and underground mining, road development, construction, utility placement, demolition, oil, gas, and underwater.

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### **EXP ENG 5713 Demolition of Buildings and Structures** (LAB 1.0 and LEC 2.0)

Provide participants with basics and solid grounding in the equipment, techniques and processes required for the demolition and remediation of mine plant and processing equipment sites and non-mining structures such as buildings, factories, bridges, etc. Field trip required. Prerequisites: Preceded or accompanied by Civ Eng 2200 or Mech Eng 2340; US citizen or permanent resident; Successful background check.

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### **EXP ENG 5721 Specialty Uses of Energetic Materials** (LEC 3.0)

Overview of special, less common uses of energetic materials and how they can be applied as a functional tool. Topics include the use of energetics in aerospace, explosive ordnance, oil field development, welding, pyrotechnics, theatrics, and cinematic special effects.

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### **EXP ENG 5914 Explosives Manufacturing** (LEC 3.0)

History of industrial explosives from discovery to what is used today. Manufacturing processes for packaged and bulk explosives are explored along with specialty explosives such as detonating cord, cast boosters, detonators, shaped charges, and commercial fireworks. Field manufacturing of explosives by mixing or gassing is also covered. Prerequisites: Successful background check, consent of instructor.

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### **EXP ENG 5922 Tunneling & Underground Construction Techniques** (LAB 1.0 and LEC 2.0)

Mechanical and conventional excavation techniques in underground tunneling and construction. Topics include tunneling layouts design, equipment and performance modeling, ground control systems including support, drainage, and structural integrity. Construction specifications, advance rate and contractual and cost estimation. Prerequisite: Consent of instructor. (Co-listed with Min Eng 5922).

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### **EXP ENG 6000 Special Problems** (IND 1.0-3.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**EXP ENG 6001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**EXP ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**EXP ENG 6070 Graduate Cooperative Experience** (LAB 3.0)

Students on an approved internship will complete a project designed by the advisor and employer. The project selected must require that student apply critical thinking skills and discipline specific knowledge in the work setting. A major report and a formal presentation are required. Prerequisite: 12 hours Exp Eng coursework.

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**EXP ENG 6080 Industry Project** (LAB 3.0)

Students who are currently employed may complete a project in their work setting designed by the advisor and employer. The project selected must require that student apply critical thinking skills and discipline specific knowledge. A major report and a formal presentation are required. Prerequisite: 12 hours Exp Eng coursework.

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**EXP ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisites: Consent of instructor required.

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**EXP ENG 6112 Explosives Regulations** (LEC 3.0)

Comprehensive coverage of the federal regulations governing the explosives industry, including those governing storage of explosives (ATF), transportation of explosives (DOT and TSA), the environment (EPA) and use of explosives (OSM, MSHA and OSHA). Prerequisite: Graduate standing.

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**EXP ENG 6212 Theory Of High Explosives** (LEC 3.0)

Study of the application of chemical thermodynamics and the hydrodynamic theory to determine the properties of high explosives; application of detonation theory to steady-state detonations in real explosives; application of the above to the blasting action of explosives. Prerequisite: Graduate Standing. (Co-listed with Min Eng 6632).

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**EXP ENG 6292 Research Methods** (LEC 3.0)

Foundations, dimensions, and methods for designing and investigating research problems. Focus on fundamentals and applied research, research methods, literature review, experimental design and experimentation, dissertation composition, concepts of originality and intellectual property. Prerequisites: PhD students only. (Co-listed with Min Eng 6992).

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**EXP ENG 6312 Scientific Instrumentation For Explosives Testing & Blasting** (LEC 1.0 and LAB 2.0)

Application of scientific principles, equipment description and operation for instrumentation of explosive events including blasting. Topics: Blast chamber design, set up, high-speed photography, motion detection and measurement, explosives sensitivity testing, explosives properties testing, vibration measurement & analysis, destruction & demilitarization. Prerequisite: Exp Eng 5612 and Successful background check.

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**EXP ENG 6412 Environmental Controls For Blasting** (LAB 1.0 and LEC 2.0)

Advanced blast mechanics; overbreak control including comprehensive coverage of perimeter and smoothwall specialist blasting techniques and geotechnical factors affecting blast vibration, limits analysis monitoring and control; air blast control including limits, monitoring and atmospheric and topographic effects. Prerequisites: Min Eng 5612, Successful background check. (Co-listed with Min Eng 6622).

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**EXP ENG 6464 Advanced Blast Vibration Analysis and Prediction** (LEC 3.0)

Advanced Blast Vibration prediction methodologies. Includes typical methods including scaled distance, linear regression, signature hole analysis, and modern improved signature hole analysis. Structural response and damage criteria for blast vibrations including considerations for frequency spectra and amplitude. Prerequisite: Exp Eng 5612.

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**EXP ENG 6767 Special Explosive Applications** (LAB 1.0 and LEC 2.0)

Advanced theory and special application of explosives other than for rock excavation. Students will be introduced to different industrial, military and government special uses such as avalanche control, explosive welding, forming, synthesis and hardening, aerospace, forest service, agriculture and oil industry applications. Prerequisites: Exp Eng 5612 or equivalent.

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## Geological Engineering (GEO ENG)

**GEO ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor is required.

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**GEO ENG 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEO ENG 5085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**GEO ENG 5090 Geological Engineering Design** (LEC 2.0 and LAB 1.0)

Geological engineering design is an open-ended project course requiring the collection of data, analysis and synthesis of that data and design of a socially acceptable, economical solution to the selected problem. Oral and written reports are required. Prerequisite: To be taken in the semester before graduation.

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**GEO ENG 5092 International Engineering and Design** (LEC 3.0)

A multi-disciplinary engineering course focused on sustainable design and technology transfer to developing countries. Course includes elements of traditional capstone design classes. Experiential learning through competitions and/or field work is a major component of the class. Prerequisites: Senior standing, instructor approval, Geo Eng 5211, Geo Eng 5247. (Co-listed with Met Eng 4510 and Cer Eng 4510).

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**GEO ENG 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**GEO ENG 5144 Remote Sensing Technology** (LAB 1.0 and LEC 2.0)

Principles of digital image processing including image enhancement and multispectral classification. Emphasis upon design and implementation of remote sensing systems and analysis of remotely sensed data for geotechnical and environmental investigations. Prerequisite: Geology 1110. (Co-listed with Geology 4310).

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**GEO ENG 5144H Remote Sensing Tech-H** (LAB 1.0 and LEC 2.0)**GEO ENG 5146 Applications Of Geographic Information Systems** (LEC 2.0 and LAB 1.0)

Applications of Geographical Information Systems and remote sensing to environmental monitoring, mineral resource exploration, and geotechnical site evaluation. Prerequisite: Geo Eng 3175 or consent of instructor. (Co-listed with Geology 4821).

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**GEO ENG 5153 Regional Geological Engineering Problems In North America** (LEC 3.0)

A physiographic approach to engineering materials and problems. Course emphasizes the distribution and engineering characteristics of soil and rock to construction and site problems and includes aggregates, foundations, excavations, surface and ground water, slope stability and arctic conditions.

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**GEO ENG 5172 Soil Science In Engineering Practice** (LEC 3.0)

A study of the ways in which soils and geologic conditions influence engineered projects. Soil formation, soil chemistry and properties to include composition, organic component, ion exchange and water relationships as well as erosion control and revegetation will be covered. Prerequisite: Geo Eng 3175.

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**GEO ENG 5173 Geologic Field Methods** (LAB 3.0)

Field practice in geologic mapping and interpretation in the Western United States using topographic base maps and aerial photos. Emphasizes the description and interpretation of stratigraphic sections, sedimentary and tectonic structures. Prerequisite: Two courses in either Geology or Geological Engineering.

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**GEO ENG 5174 Geological Engineering Field Methods** (LAB 3.0)

Instruction in methods of field investigation required for geological engineering studies. Course will include procedures for qualitative and quantitative data collection for characterizing surficial geologic conditions, groundwater and surface water investigations, and other engineering activities. Written reports and field trip required.

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**GEO ENG 5211 Introduction to International Engineering and Design Lab** (LAB 1.0)

The lab for multi-disciplinary design will be as follows: Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by GEO ENG 5247.

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**GEO ENG 5233 Risk Assessment In Environmental Studies** (LEC 3.0)

This course will present the concepts required to assess the human health and environmental risks resulting from contaminants in soil and groundwater. Course topics include evaluation of data sets, exposure calculation, chemical fate and transport, and development of conceptual site models.

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**GEO ENG 5235 Environmental Geological Engineering** (LEC 3.0)

Introduction to engineering geologic mapping for site selection for solid waste disposal facilities; landfill site selection, design, permitting, construction, operation, and closeout/reclamation. Prerequisites: Geo Eng 3175, accompanied or preceded by Civ Eng 3715.

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**GEO ENG 5237 Geological Aspects Of Hazardous Waste Management** (LEC 3.0)

Nature and classification of hazardous wastes; federal and state regulation for treatment and disposal; geological characterization of facility sites; design of impoundments, storage and containment facilities; ground water monitoring and protection; site permitting and licensing planning. Prerequisite: Geo Eng 3175.

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**GEO ENG 5239 Groundwater Remediation** (LEC 3.0)

A survey of conventional and innovative techniques for remediation of contaminated groundwater. Topics include groundwater cleanup standards, physico-chemical properties of groundwater and contaminants, fate and transport of contaminants in the subsurface, hydrogeologic site characterization, and selection process of a remedial technology. Various computer programs developed to assist in preliminary selection and design of remediation technologies will be used. Prerequisite: Geo Eng 5331.

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**GEO ENG 5247 Introduction to International Engineering and Design** (LEC 2.0)

A multi-disciplinary design course focused on sustainable design and technology transfer to developing countries. Students will develop a work plan to address design objectives and other considerations including scheduling, budgeting, environmental impacts, and life cycle design. Prerequisites: Senior standing, instructor approval, accompanied by Geo Eng 5211.

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**GEO ENG 5276 Advanced Environmental Aspects Of Mining** (LEC 3.0)

Applied and fundamental research issues pertaining to: permitting -- the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, nonmetal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Course project. (Co-listed with Min Eng 5742).

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**GEO ENG 5315 Advanced Statistical Methods in Geology and Engineering** (LEC 3.0)

Application of statistical methods to study of geologic materials and practices, with emphasis on reliable interpretation of laboratory and field data for water, hydrocarbon, and mineral exploration, research, and engineering as well as other aspects of geological engineering. Prerequisites: Geo Eng 4115 or Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117.

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**GEO ENG 5320 Groundwater Modeling** (LEC 3.0)

This course is an introduction to advanced modeling techniques for understanding flow and transport in porous media under different hydrologic conditions. Emphasis is placed on both theoretical and practical modeling considerations. Computer demonstrations are incorporated. Practical applications are emphasized. Prerequisite: Civ Eng 3330 or Geo Eng 5331.

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**GEO ENG 5331 Subsurface Hydrology** (LAB 1.0 and LEC 2.0)

Introduction to the theory and engineering concepts of the movement of subsurface fluids. Hydraulic characteristics of earth materials, aquifer characterization, and flow prediction. Engineering problems related to subsurface fluids. Prerequisites: Geo Eng 1150 or equivalent, Math 1215.

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**GEO ENG 5332 Fundamentals of Groundwater Hydrology** (LEC 3.0)

Focus on fundamental analysis and survey of groundwater hydrology with emphasis on practical geo-environmental and subsurface hydrology issues of interest to working professionals. Topics will include general hydrology, surface and subsurface interconnection, basic groundwater flow and well test analysis, and a brief intro to contaminant transport.

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**GEO ENG 5381 Intermediate Subsurface Hydrology And Contaminant Transport Mechs** (LAB 1.0 and LEC 2.0)

A study of the physical/chemical properties of rocks and sediments in the subsurface environment. Emphasis is put on waterrock properties such as permeability, capillarity, and mechanical dispersion. Both microscopic and macroscopic approaches are used. Prerequisites: Geo Eng 5331, Geo Eng 5332, or Geol 4411.

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**GEO ENG 5415 Soil Mechanics for Geoprosessionals** (LEC 3.0)

The basic principles of soil mechanics necessary for professionals to practice in the field of geoconstruction. Topics related to the practical aspects of engineering include: soil classification, index properties, water flow through soils, compaction, compressibility, and shear strength. These basic principles will be applied to real world problems.

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**GEO ENG 5441 Engineering Geology And Geotechnics** (LEC 3.0)

Study of procedures and techniques used to evaluate geologic factors for site selection and the design of engineered structures. Prerequisite: Geo Eng 3175.

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**GEO ENG 5443 Subsurface Exploration** (LAB 1.0 and LEC 2.0)

Lectures and field and laboratory exercises in the use of geologic and geophysical techniques for evaluation of subsurface geology and resources. Prerequisite: Geo Eng 1150.

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**GEO ENG 5471 Rock Engineering** (LEC 3.0)

Data requirements for design; engineering properties of rock; characterization of fractures and rock masses; stereonet analysis of discontinuities; graphic analysis of failure; ground stress distribution; tunnel construction methods; ground support principles; selection of tunneling equipment; and specifications for underground construction. Prerequisite: Geo Eng 3175.

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**GEO ENG 5556 Renewable Energy Systems** (LEC 3.0)

Introduction to the theory and performance prediction of typical renewable energy systems such as, but not limited to, those based on energy from the sun, wind and water, and geothermal. The use of environmental data, including stochastic modeling, for renewable energy system (including wind turbine, photovoltaic, and geothermal) design is addressed. Prerequisites: Math 3304, Physics 2135, and preceded or accompanied by Geo Eng 4115 or any Probability and Statistics class. Junior or senior standing is required.

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**GEO ENG 5575 Aggregates And Quarrying** (LEC 3.0)

Properties and uses of aggregates. Finding aggregate deposits and methods of extraction. Aggregate processing. Aggregate testing. Economics and politics of aggregates. Special topics in aggregates and quarrying. Prerequisites: Geo Eng 1150, Geo Eng 3175.

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**GEO ENG 5642 Military Geology** (LEC 3.0)

This course will familiarize geologists, geophysicists, civil and geological engineers with the fundamental principles of physical geology, geohydrology and geomorphology as applied to military problems, such as development of fortifications, core infrastructure, water resources and combat engineering requirements. Prerequisite: Geo Eng 3175 or graduate standing.

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**GEO ENG 5736 Geophysical Field Methods** (LEC 2.0 and LAB 1.0)

Imaging of selected subsurface features and engineering structures using various geophysical tools. Special emphasis is placed on ground penetrating radar and surface wave techniques. One field trip at student expense required. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5736).

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**GEO ENG 5761 Transportation Applications of Geophysics** (LEC 2.0 and LAB 1.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geophys 5761 and Civ Eng 5750).

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**GEO ENG 5782 Environmental and Engineering Geophysics** (LEC 2.0 and LAB 1.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 2222. (Co-listed with Geophys 5782).

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**GEO ENG 5810 Fundamentals of Space Resources** (LEC 3.0)

Introduction to the science of the mineral resources of space, and to the engineering of extracting them for human use.

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**GEO ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEO ENG 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEO ENG 6010 Seminar** (RSD 1.0)

Discussion of current topics. Prerequisite: Graduate student.

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**GEO ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEO ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEO ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**GEO ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

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**GEO ENG 6146 Advanced Remote Sensing And Image Processing** (LEC 2.0 and LAB 1.0)

Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Geo Eng 5146. (Co-listed with Geology 6341).

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**GEO ENG 6235 Advanced Concepts Of Environmental Geological Engineering** (LEC 3.0)

Application of the principles of geology to the solution of engineering problems in environmental protection and remediation. Topics will include the study of geologic processes and the evaluation of geologic materials as they affect the potential for groundwater contamination, susceptibility of soils to erosion, characterization of the geologic environment for site suitability and the analysis of the criteria necessary for the selection of technologies for minimizing environmental impact. Prerequisite: Graduate level course in environmental geologic studies.

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**GEO ENG 6237 Advanced Geological & Geotechnical Design For Hazardous Waste Mgt** (LEC 3.0)

Geological and geotechnical design factors for hazardous waste management facilities and remedial actions (cleanup) of uncontrolled hazardous waste sites. Prerequisite: Geo Eng 5237 or consent of instructor.

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**GEO ENG 6331 Advanced Subsurface Hydrology** (LEC 3.0)

Advanced treatment of selected topics in subsurface hydrology, including groundwater contamination, contaminant transport, land disposal of wastes, aquifer test analysis, injection well technology, etc. Applied hydrogeologic site analysis and flow and transport modeling through solution of selected case examples. Prerequisite: Geo Eng 5331 or equivalent.

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**GEO ENG 6332 Numerical Methods In Subsurface Flow** (LEC 3.0)

Development of governing balance equations, constitutive laws and mathematical models of groundwater flow and contaminant transport in porous media. Solution of mathematical models by finite difference and finite element methods for various boundary and initial conditions. Prerequisites: Geo Eng 5331, Comp Sci 1970.

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**GEO ENG 6400 Practice Oriented Project** (IND 3.0)

This class will consist of a single term project. Students will, in consultation with the instructor, pick a topic relevant to their studies, and produce a comprehensive, in depth, professionally written report, including a literature review on the state of the practice on that topic. Prerequisites: Limited to students enrolled in the Masters of Engineering (M.E.) in Geotechnics Program.

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**GEO ENG 6407 Inca Civilization Geotechnical Engineering Practices** (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Civ Eng 6760).

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**GEO ENG 6441 Geotechnical Construction Practice** (LEC 3.0)

Advanced level lecture topics on procedures used for site characterization, standards for earthquake grading and construction, including embankments, building pads, retention structures, roads, levees, and earthen dams. Specific emphasis on preparation of documents involved in such work and engineer's responsibilities. Prerequisite: Geo Eng 5441.

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**GEO ENG 6477 Discontinuous Rock** (LEC 3.0)

Nature and properties of discontinuous rock masses, genesis and properties of joints, role of joints in rock shear strength, slope of stability of jointed rock, fracture flow hydrogeology. Modeling of the mechanical behavior of fractured rock. Prerequisite: Min Eng 4823 or Geo Eng 5471.

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**GEO ENG 6625 Applications in Geological Engineering** (LEC 3.0)

Content is focused on practical aspects of geological engineering. Geotechnical, environmental and geohydrologic case studies are presented to illustrate concepts and relate theory to applications.

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**GEO ENG 6736 Advanced Geophysical Methods** (LEC 1.0 and LAB 2.0)

Geophysical field data will be acquired at selected study sites with the objective of imagine the shallow subsurface and/or built structures. Registrants will process and interpret the acquired non-invasive imaging data using ground truth as a constraint. Prerequisite: Graduate Standing.

**GEO ENG 6782 Surface Waves (MASW) and Ground Penetrating Radar (GPR)** (LAB 1.0 and LEC 2.0)

Geological engineering applications of surface wave and ground penetrating radar methods are emphasized. Field data will be acquired, processed and interpreted. Prerequisites: Geo Eng 1150 or Civ Eng 3715 or equivalent, and graduate standing.

**GEO ENG 6784 Advanced Engineering And Environmental Geophysics** (LEC 3.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential induced polarization, seismic, electromagnetic and GPR methods as applied to the solution of engineering and environmental problems. Prerequisite: Admittance into USAES-S&T Co-operative Degree Program. (Co-listed with Geophys 5251).

## Geology (GEOLOGY)

**GEOLOGY 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**GEOLOGY 5001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**GEOLOGY 5010 Seminar** (LEC 0.50)

Discussion of current topics.

**GEOLOGY 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**GEOLOGY 5085 Internship** (IND 3.0)

Students will select, with their committee's advice, problems for investigation and preparation of a graduate research proposal. Problems must provide higher level experiential learning consistent with a graduate degree in geology. Assessment is based upon the quality of written and oral presentations and supervisor's evaluation. Repeatable for credit. Prerequisite: Graduate Standing.

**GEOLOGY 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

**GEOLOGY 5100 Professional Geoscience Skills** (LEC 3.0)

Development and communication of complex topics in the geosciences is required for successful post-MS career advancement. Best practices for developing these skills in the geosciences will be critiqued weekly, culminating with poster and oral presentations. Assessment by peer-review and self-evaluation. Topics selected from geosciences careers. Prerequisites: Graduate Standing.

**GEOLOGY 5111 Advanced Physical Geology** (LEC 3.0)

Examination of topics concerned with the physical properties of earth materials, processes affecting change of the surface and interior of the earth, and the driving forces causing these changes. Weekly critical assessment of literature, and an oral presentation and term paper required. Prerequisite: Consent of instructor.

**GEOLOGY 5121 Advanced Historical Geology** (LEC 2.0 and LAB 1.0)

Study of the physical and biological history of the Earth beginning with the origin of the solar system up to the present. Emphasis will be placed on processes that shaped the Earth and its ecosystems. Prerequisite: Entrance requirements for the MST program in Earth Science.

**GEOLOGY 5311 Depositional Systems** (LEC 3.0)

Development of three dimensional depositional models using Walther's Law, Walther's Warning and seismic stratigraphy. Emphasis on overall geometries and internal porosity and permeability characteristics of aquifers and hydrocarbon reservoirs. Includes 3-D models for clastic, carbonate and evaporate sequences. Prerequisites: Geology 1110 or Geo Eng 1150; accompanied or preceded by both Geology 3310 and Geology 3620.

**GEOLOGY 5511 Applied Petroleum Geology** (LAB 2.0 and LEC 1.0)

The principles of petroleum geology are applied in solving hydrocarbon exploration and developmental problems. Geological and economical techniques for evaluating hydrocarbonbearing reservoirs are presented, with methods for decisionmaking under conditions of extreme uncertainty. Prerequisite: Consent of instructor.

**GEOLOGY 5513 Petroleum Geology** (LAB 1.0 and LEC 2.0)

Principles of origin, migration, and accumulation of oil and gas. The laboratory introduces the procedures used for exploration, and development of hydrocarbon resources. Prerequisites: Geology 1110 or Geo Eng 1150; accompanied or preceded by both Geology 3310 and Geology 3620.

**GEOLOGY 5521 Coal Petrology** (LEC 3.0)

Formation, composition, and properties of coals. Discussion of the geology of selected coal deposits, the analysis of coal, and the optical identification of coal minerals. Prerequisite: Permission of instructor.

**GEOLOGY 5611 Granites And Rhyolites** (LAB 1.0 and LEC 3.0)

Processes governing the generation and crystallization of felsic magma will be covered, with specific reference to: 1) crust vs mantle sources, 2) melt migration and emplacement, 3) magma chamber dynamics, 4) the volcanic-plutonic connection, and 5) the relationship to tectonic setting. A field trip at the student's expense is required. Prerequisite: Geology 2620.

**GEOLOGY 5631 Carbonate Petrology** (LEC 2.0 and LAB 1.0)

Petrology, chemistry and sedimentology of carbonates and other associated chemical sedimentary rocks. Prerequisites: GEOLOGY 2620, 3620 and CHEM 1320 or equivalent; GEOLOGY 3410 recommended.

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**GEOLOGY 5641 Advanced Igneous Petrology** (LEC 2.0 and LAB 1.0)

The genesis of eruptive rocks as evidenced by the physico-chemical conditions of formation of their constituent minerals. A critical examination of various magmatic processes. Use of advanced petrographic techniques. Prerequisites: GEOLOGY 4631.

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**GEOLOGY 5661 Advanced Stratigraphy and Basin Evolution** (LEC 3.0)

Advanced topics in sedimentary geology including: tectonic controls on sedimentary basin development, global sequence stratigraphy, regional facies and diagenetic patterns, basin hydrogeology, thermal evolution of basins and distribution of economic resources. This course should be preceded or accompanied by Geology 3410. Prerequisites: Geology 3620 and Geology 3310.

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**GEOLOGY 5671 Clay Mineralogy** (LAB 1.0 and LEC 2.0)

Mineral structure, geochemical properties, occurrence, environment, and uses of clays. Determination of physical properties, optics, x-ray diffraction, and thermal features of clays. Field trip fee required. Prerequisites: Geology 2610 and 3410, or Chem 2310, or Civ Eng 5715, or Geo Eng 5172.

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**GEOLOGY 5679 Field and Laboratory Studies in Earth Science** (LAB 3.0)

Hands-on laboratory and field experiences in the Earth Sciences. This course is designed to be taught in an intensive three week session during the summer on the S&T campus. Prerequisites: GEOLOGY 2096 or 5121 or equivalents.

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**GEOLOGY 5681 Lidar Principles and Application** (LEC 3.0)

Provides a comprehensive understanding of light detection and ranging (lidar) technology as it has been developed for commercial use; various methods of deploying technology for collection of data for mapping, engineering and science, and application of the data using specialized software for editing and processing point cloud data. Assumes GIS experience. Prerequisite: Senior or graduate standing.

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**GEOLOGY 5741 Micropaleontology** (LEC 2.0 and LAB 1.0)

This course studies the fossil and soft-body characteristics of bacteria, protists, microinvertebrates and organic-walled microfossils (palynomorphs). Focused discussions on systematics, evolutionary histories, paleoecology, and geologic applications of the microfossil groups. Extraction of foraminifera and palynomorphs from rocks in lab. Prerequisite: Geology 4630.

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**GEOLOGY 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEOLOGY 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEOLOGY 6010 Seminar** (IND 0.0-6.0)

Discussion of current topics.

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**GEOLOGY 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEOLOGY 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEOLOGY 6085 Internship** (IND 3.0)

Students will select, with their committee's advice, problems for investigation and preparation of a graduate research proposal. Problems must provide higher level experiential learning consistent with a graduate degree in geology. Assessment is based upon the quality of written and oral presentations and supervisor's evaluation. Repeatable for credit. Prerequisite: Graduate standing.

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**GEOLOGY 6097 Advanced Geologic Field Methods** (LEC 3.0)

Advanced instruction in planning and implementation of geologic field campaigns, development of an appropriate scientific plan, including logistics, safety, and supervision of field personnel in a manner consistent with professional practices. Emphasis placed upon reflection on projects outcomes supervised with faculty oversight. Field Trip fee required.

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**GEOLOGY 6098 Advanced Geologic Field Methods** (LEC 3.0)

Adv. instruction in theory and practice of qualitative/quantitative description of spatial relationships of rock types in areas exhibiting complex deformation. Emphasis on expl. learning where students plan, implement, and reflect on outcomes for sev. scientific field campaigns in a manner consistent with prof. scientific practices. Field trip fee required.

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**GEOLOGY 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation.

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**GEOLOGY 6100 Advanced Professional Geoscience Skills** (LEC 3.0)

Communication of complex research topics in the geosciences is required for successful post-doctoral career advancement in both academic and non-academic career paths. Best practices for developing and proposing scientific ideas in the geosciences will be critiqued weekly. Assessment of research proposals presentations includes peer-and self-evaluation. Prerequisites: Doctoral Graduate Standing.

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**GEOLOGY 6211 Geodynamics** (LEC 3.0)

The applications of continuum physics to geological and petroleum engineering problems. Topics include plate tectonics, stress and strain in solids, elasticity and flexure, heat transfer, gravity, fluid mechanics, rock rheology, faulting, and flow in porous media. Prerequisites: Math 2222 and Geology 3310. (Co-listed with Pet Eng 6711).

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**GEOLOGY 6311 Advanced Structural Geology** (LAB 1.0 and LEC 2.0)

The course provides theoretical background, analytical techniques, and hands-on experience for analyzing geologic structures at a variety of scales hand sample to global. Prerequisites: Geology 3310, Geophys 4096.

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**GEOLOGY 6321 Analytical Structural Geology** (LAB 1.0 and LEC 2.0)

The course provides theoretical background, analytical techniques, and hands-on experience, for quantifying processes that lead to the formation and evolution of rocks and structures produced as a result of deformation at a variety of scales - hand sample to global. Poster - and oral - presentations, and a research paper required. Prerequisites: Geology 3310, Geophys 4096.

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**GEOLOGY 6331 Geotectonics** (LEC 3.0)

A critical study of the origin, and differentiation of the earth, evolution of the crust, and plate tectonics. Geology of the continents and ocean basins. Regional tectonic analysis of precambrian shields, platforms, orogenic belts, and a review of internal energy sources. Emphasis is on North America. Prerequisite: Geology 3310.

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**GEOLOGY 6341 Advanced Remote Sensing And Image Processing** (LEC 2.0 and LAB 1.0)

Quantitative methods of utilizing remote sensing technology for terrain analysis. Digital image processing of landsat and/or aircraft scanner data for mineral resource studies and geological engineering applications. Prerequisite: Geo Eng 5146. (Co-listed with Geo Eng 6146).

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**GEOLOGY 6351 Advanced Geochemistry** (LEC 3.0)

A study of the absolute and relative abundance of elements and isotopes in the Earth, principles of element transport, formation of the Earth's crust, mineral deposits, and soils. Field trip fee required. Prerequisite: Geology 3410.

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**GEOLOGY 6411 Advanced Isotope Geochemistry** (LEC 2.0 and LAB 1.0)

The use of radiogenic and stable isotopes in geology in the study of the evolution of Earth, crust, mantle, and the Solar System as well as applications to geothermometry, ore petrogenesis, paleontology, and the global climate system. Prerequisites: Geology 2620, 3620, 3410.

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**GEOLOGY 6421 Environmental Geology** (LEC 3.0)

Overview of environmental problems facing humans. Emphasis will be placed on surface and groundwater pollution, geological hazards, and pressures on Earth's ecosystems and natural resources by urbanization and population growth. Prerequisites: GEOLOGY 1110 or 1120 or equivalents.

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**GEOLOGY 6511 Advanced Petroleum Geology** (LEC 1.0 and LAB 2.0)

The principles of petroleum geology are applied in solving hydrocarbon exploration and developmental problems. Various types of oil and gas accumulations are reviewed in detail. Study of criteria useful in evaluating the petroleum potential of undrilled areas. Special investigation assignment is required. Prerequisite: Geology 3310, Geology 5513, Geology 5661, or Geology 6811.

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**GEOLOGY 6521 Advanced Ore Microscopy** (LEC 1.0 and LAB 2.0)

A study of ore suites utilizing various advanced, quantitative ore microscopy techniques including hardness, spectral reflectance, indentation, color, rotation property measurements, fluid inclusion geothermometry, and salinity measurements. Laboratory study includes demonstration and operation of the lumnoscope and other microbeam techniques. Prerequisite: Geology 4521.

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**GEOLOGY 6531 Applied Ore Microscopy** (LAB 2.0 and LEC 1.0)

Application of ore microscopic and petrographic techniques to problems in ore beneficiation, pelleting, sintering, smelting, refining, refractories, cement, mining, and exploration. Discussions and laboratories are based upon industrial case histories. Prerequisite: Geology 4521.

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**GEOLOGY 6541 Geology of Natural Resources** (LEC 3.0)

The origin and distribution of economically important natural resources including soils, water resources, metals, non-metals, building materials, petroleum, and other energy resources. Prerequisites: GEOLOGY 1110 or 1120 or equivalents.

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**GEOLOGY 6551 Ore Deposition** (LAB 1.0 and LEC 2.0)

An advanced study of mineral deposits, time and space in deposition, theories of deposition and their effect on exploration. Discussions based on maps, logs, and samples from the world's typical mineral deposits. Two all day field trips at student expense required. Prerequisite: Geology 3511.

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**GEOLOGY 6611 Advanced Palynology** (LEC 1.0 and LAB 2.0)

Study of organic-walled microfossils, and the processes of sporopollenin preservation, sedimentation and palynofacies. Chronicle of Phanerozoic palynology in lectures. Major emphasis on independent palynostratigraphic research and applications, such as biostratigraphy, paleoclimatology and paleoenvironments. Prerequisite: Geology 3631 or Geology 5741.

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**GEOLOGY 6621 Clastic Sedimentary Petrology** (LAB 1.0 and LEC 2.0)

Petrology and petrography of clastic sedimentary rocks. Emphasis on origin, diagenesis and description of clastic, sedimentary rocks. Prerequisite: Geology 3620.

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**GEOLOGY 6651 Granite and Rhyolite Petrogenesis** (LAB 1.0 and LEC 3.0)

The origin of granites and rhyolites with respect to extreme fractionation, crustal anatexis, magma mixing, and tectonic setting will be explored through critical reading of the literature and examination of hand samples and thin sections from classic geologic terranes. A research paper is required as well as a field trip at the student's expense. Prerequisite: Geology 2620.

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**GEOLOGY 6711 Advanced Paleoclimatology and Paleoecology** (LEC 3.0)

Advanced study of paleoclimatic and paleoecologic processes since the Archean, and the interpretation of Holocene climate changes, including human impacts. Extensive presentations and discussions of current ideas and techniques in paleoclimatic studies. Prerequisite: Geology 3620.

**GEOLOGY 6811 Sedimentary Basin Analysis** (LEC 3.0)

An advanced study of stratigraphic, diagenetic and tectonic processes in sedimentary basins. Prerequisites: Geology 3310, 3620, 3410 or 4441 or 4451.

## Geophysics (GEOPHYS)

**GEOPHYS 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**GEOPHYS 5001 Special Topics** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**GEOPHYS 5010 Seminar** (LEC 0.50)

Discussion of current topics.

**GEOPHYS 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**GEOPHYS 5096 Global Tectonics** (LEC 3.0)

An integrated view of the Earth's structure and dynamics with an emphasis on information gained through geophysical methods. Topics include seismology, heat flow, gravity, rheological and compositional structure, plate motions and intermotions, and mantle driving mechanisms for plate tectonics. Prerequisite: Geology 3310.

**GEOPHYS 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**GEOPHYS 5202 Exploration and Development Seismology** (LEC 2.0 and LAB 1.0)

Principles of reflection seismology as applied to the delineation of geologic structures and the determination of stratigraphy and lithology. Emphasis on both the capabilities and limitations of the seismic method. The laboratory utilizes both modeled and actual seismic data. Prerequisites: Math 1208 or Math 1214; Geology 1110 or Geo Eng 1150.

**GEOPHYS 5211 Seismic Stratigraphy** (LEC 2.0 and LAB 1.0)

A study of the seismic expression of depositional models. Reflection patterns and reflection amplitudes are interpreted to determine bed thicknesses, fluid content, depositional environment, and lithology. Special data acquisition and processing techniques are examined. Prerequisites: Geophys 4521, Geology 3310, 3620.

**GEOPHYS 5221 Wave Propagation** (LEC 3.0)

A study of Hamilton's principle and energy theorems, fundamentals of plane wave theory, waves in stratified fluids, elastic waves in solids, electromagnetic and hydromagnetic radiation, and Allen's functions and point sources. Prerequisites: Geophys 281, 3221.

**GEOPHYS 5231 Seismic Data Processing** (LEC 2.0 and LAB 1.0)

Introduction to seismic data processing. Topics to be covered include statics corrections, filtering, velocity analysis, deconvolution, stacking and migration. The course has a field component to record seismic data. If this is offered in the summer, an off-campus trip may be needed. Extra fee may be charged to cover the field expenses. Prerequisites: Geophys 3210 or Geophys 5202.

**GEOPHYS 5241 Advanced Electrical And Electromagnetic Methods In Geophysical Exp** (LAB 1.0 and LEC 2.0)

Theory of the electrical geophysical methods as applied to subsurface investigations addressing geologic, engineering, groundwater and contaminant transport problems. Course content includes both passive and active methods and recent advances in the application of these methods. Course will include a field component illustrating application of techniques to local problems. Prerequisites: Geophys 3251, Math 2222.

**GEOPHYS 5261 Computational Geophysics** (LAB 2.0 and LEC 1.0)

Scientific programming in a UNIX/Linux environment, with emphasis on solving geophysical problems such as linear and nonlinear inversion, spectral analysis, seismicity, seismic wave attenuation, shear-wave splitting, and seismic tomography. Prerequisite: Geophys 3210.

**GEOPHYS 5736 Geophysical Field Methods** (LEC 2.0 and LAB 1.0)

Imaging of selected subsurface features and engineering structures using various geophysical tools. Special emphasis is placed on ground penetrating radar and surface wave techniques. One field trip at student expense required. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5736).

**GEOPHYS 5761 Transportation Applications of Geophysics** (LAB 1.0 and LEC 2.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5761 and Civ Eng 5750).

**GEOPHYS 5782 Environmental and Engineering Geophysics** (LAB 1.0 and LEC 2.0)

An introduction to the theory and application of the gravity, magnetic, resistivity, self-potential, induced polarization and electromagnetic methods as applied to the solution of engineering and environmental problems. Prerequisite: Math 2222. (Co-listed with Geo Eng 5782).

**GEOPHYS 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**GEOPHYS 6001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**GEOPHYS 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**GEOPHYS 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**GEOPHYS 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**GEOPHYS 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**GEOPHYS 6211 Advanced Seismic Interpretation** (LAB 1.0 and LEC 2.0)

The integration of geologic information, well log data and seismic information for interpreting the earth's subsurface using advanced 3-D seismic interpretation software packages. Reservoir identification and evaluation as well as horizon and formation attributes are included. Prerequisites: Geophys 3210 or Geophys 5202.

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**GEOPHYS 6231 Advanced Seismic Data Processing** (LEC 2.0 and LAB 1.0)

Theory and application of seismic data processing. Topics to be covered include convolution, correlation, deconvolution, 2-D filtering, migration and inversion. Prerequisites: Geophys 5202, 5231, Stat 3115.

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**GEOPHYS 6241 The Theory of Elastic Waves** (LAB 1.0 and LEC 2.0)

A mathematical study of elastic waves in the layered earth. Prerequisites: Geophys 3210.

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**GEOPHYS 6251 Geophysical Inverse Theory** (LAB 1.0 and LEC 2.0)

A study of inverse theory applied to geophysical data, focusing on the relationship between data and model spaces and ways to estimate model parameters via global and local optimization techniques. Prerequisites: Geophys 3210 or Graduate Standing in GGPE.

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## Info Science & Technology (IS&T)

**IS&T 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**IS&T 5001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

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**IS&T 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**IS&T 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**IS&T 5131 Foundations of Computer Architecture** (LEC 3.0)

Design-oriented foundations of computer components and operation. Standard codes; number systems; base conversions; computer arithmetic; boolean algebra; operating system components including memory management, device management; plus related computer architecture topics. Research paper required. Prerequisites: Graduate Standing, strong programming knowledge.

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**IS&T 5168 Law and Ethics in E-Commerce** (LEC 3.0)

Provides the ethical framework to analyze the ethical, legal, and social issues that arise for citizens and computer professionals regarding the computerization of society. Topics include: free speech, privacy, intellectual property, product liability, and professional responsibility. (Co-listed with Philos 4368).

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**IS&T 5251 Technological Innovation Management and Leadership** (LEC 3.0)

The course focuses on the knowledge and skills necessary for the development and implementation of effective strategies for the management of technology-based organizations. This involves: developing a general management perspective on technology and innovation, examining the problems of new product development, identifying distinctive technological competencies, licensing and marketing technologies, assessing the organizational and industrial context of technology. Prerequisite: Senior or Graduate Standing.

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**IS&T 5420 Business Analytics and Data Science** (LEC 3.0)

Analysis of large business data sets via statistical summaries, cross-tabulation, correlation, and variance matrices. Techniques in model selection, prediction, and validation utilizing general linear and logistic regression, Bayesian methods, clustering, and visualization. Extensive programming in R is expected. Prerequisites: Calculus, Statistics, and Programming knowledge.

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**IS&T 5423 Foundations of Data Management** (LEC 3.0)

Foundational concepts of database management systems. Issues in database architecture, design, administration, and implementation. Extensive use of SQL with Oracle to create and manage databases. Significant project dealing with triggers or stored procedures. Prerequisites: Strong programming knowledge required.

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**IS&T 5520 Data Science and Machine Learning with Python** (LEC 3.0)

Examines data science methodologies for scraping, manipulating, transforming, cleaning, visualizing, summarizing, and modeling large-scale data as well as supervised and unsupervised machine learning algorithms applied in various business analytics and data science scenarios. Python libraries such as Pandas, NumPy, Matplotlib, and Scikit-learn are utilized. Prerequisites: One of Stat 3111, Stat 3113, Stat 3115, or Stat 3117; one of IS&T 1552, IS&T 1562, Comp Sci 1575; for Graduate Students: knowledge of calculus, statistics, and programming.

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**IS&T 5535 Machine Learning Algorithms and Applications** (LEC 3.0)

Introduces techniques of modern machine learning methods with applications in marketing, finance, and other business disciplines. Topics include regression, classification, resampling methods, model selection, regularization, decision trees, support vector machines, principal component analysis, and clustering. R programming is required. Prerequisites: One of Stat 3111, Stat 3113, Stat 3115, Stat 3117; one of IS&T 1552, IS&T 1562, Comp Sci 1575; or Graduate Standing with knowledge of calculus, statistics, and programming.

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**IS&T 5652 Advanced Web Development** (LEC 3.0)

Advanced web development techniques to provide dynamic interaction; methods for extracting and delivering dynamic information to/from web servers - a hands-on approach. Emphasis on interaction with servers; mobile software development; processing of graphics and web video. Project work is required. Prerequisites: IS&T 4654; one of IS&T 1551, IS&T 1561.

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**IS&T 5885 Human-Computer Interaction** (LEC 3.0)

Introduction to the field of Human-Computer Interaction (HCI). Students examine issues and challenges related to the interaction between people and technology. The class explores the social and cognitive characteristics of people who use information systems. Students learn techniques for understanding user needs, interface prototyping & interface evaluation.

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**IS&T 5886 Prototyping Human-Computer Interactions** (LEC 3.0)

This course explores novel HCI and UX technologies as well as methods and tools for creating system prototypes, including best practices and guidelines for optimal user experiences. Example concepts include mobile applications, behavioral monitoring, gamification, natural user interfaces, haptics, and computers as social actors. Prerequisite: Preceded or accompanied by IS&T 5885.

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**IS&T 5887 Human-Computer Interaction Evaluation** (LEC 3.0)

This course covers research and analysis methods and tools for evaluation of the impact of information technology systems on humans and organizations. The focus will be on practical evaluation with the goal of providing recommendations for improving system functionality and usability. Prerequisite: Preceded or accompanied by IS&T 5885.

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**IS&T 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**IS&T 6001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

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**IS&T 6050 Continuous Registration** (LEC 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**IS&T 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**IS&T 6261 Advanced Information Systems Project Management** (LEC 3.0)

Project management principles, first from a general perspective, and then focused specifically on information system application development are explored. Topics include requirements analysis, project scheduling, risk management, quality assurance, testing, and team coordination. Report writing and research literature searches are required. Prerequisites: Strong programming knowledge required.

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**IS&T 6335 Mobile Technology for Business** (LEC 3.0)

Overview of mobile technology use in business environments. Topics include: mobile industry; mobile network and wireless standards; mobile devices; mobile web design and app development; social and user experience issues; mobile marketing and commerce. Project required.

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**IS&T 6336 Foundations of Internet Computing** (LEC 3.0)

The foundations of Internet Computing include computer networks and Web sites. Networks are covered thoroughly and research directions for networking and information security are discussed. Web site design and research findings about site usability considerations are examined. Prerequisite: IS&T MS entrance requirements, including solid programming knowledge.

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**IS&T 6443 Information Retrieval and Analysis** (LEC 3.0)

Covers the applications and theoretical foundations of organizing and analyzing information of textual resources. Topics include information storage and retrieval systems, web search engines, text mining, collaborative filtering, recommender systems. Students will also learn the techniques with the use of interactive tools such as SAS. Prerequisite: ERP 5410 or statistics knowledge.

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**IS&T 6444 Essentials of Data Warehouses** (LEC 3.0)

This course presents the topic of data warehouses and the value to the organization. It takes the student from the database platform to structuring a data warehouse environment. Focus is placed on simplicity and addressing the user community needs. Project required. Prerequisite: IS&T 5423 or equivalent relational database experience. (Co-listed with ERP 6444).

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**IS&T 6445 Database Marketing** (LEC 3.0)

Intro to methods and concepts used in database marketing: 1) predictive modeling techniques (e.g., regression, decision trees, cluster analysis) and 2) standard processes for mapping business objectives to data mining goals to produce a deployable marketing model. Metrics like lifetime value of a customer and ROI will be covered. Several application areas covered. Prerequisite: Statistics understanding, programming understanding, familiarity with spreadsheets.

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**IS&T 6448 Building the Data Warehouse** (LEC 3.0)

Data modeling and processes needed to populate a data warehouse; tradeoffs among several models and tools; technical issues that are faced, such as security, schemas, Web access, other reporting techniques. Prerequisite: IS&T 6444.

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**IS&T 6450 Information Visualization** (LEC 3.0)

Topics/activities include: the visualization development framework, traditional presentations of data, human perception and aesthetics, colorspace theory, visualization algorithms and software, case studies of modern topology, research into visualization algorithms and implementations in R. Students will produce significant programs and visualizations. Prerequisites: Statistics, Calculus, and Programming Knowledge.

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**IS&T 6641 Advanced Digital Commerce and the Internet of Things** (LEC 3.0)

Fundamental concepts of management and application to IT and support of commerce. Examines use of IT in business processes and everyday interactions such as IoT. Explores management issues of integrating IT into processes to run businesses better. Includes a major end-of-semester project. Prerequisites: Knowledge of management information systems.

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**IS&T 6654 Advanced Web and Digital Media Development** (LEC 3.0)

This course covers advanced techniques and tools for the design and development of web-based media, including text, graphics, animation, audio, and video. This course is an advanced version of Web and Digital Media Development, with additional assignments.

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**IS&T 6680 Advanced Web and New Media Studies** (LEC 3.0)

The course covers web culture, including topics such as social media; citizen journalism, crowd intelligence, privacy, and copyright. This course is an advanced version of Intro to Web Studies, with additional assignments.

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**IS&T 6780 Adv Human and Organizational Factors in Cybersecurity** (LEC 3.0)

In-depth examination of human and organizational factors in cybersecurity and information assurance. Examines current challenges to protecting the integrity, availability, and confidentiality of information, as well as tools, methods, principles, and analytics for fraud prevention, insider threat detection, and forensic investigations. Project Required. Prerequisite: None, but recommended: IS&T 3333 or IS&T 6336 or Comp Sci 3600 or another introductory cybersecurity or information assurance course.

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**IS&T 6887 Research Methods in Business and IS&T** (LEC 3.0)

This course covers quantitative and qualitative research methods for exploring the interaction between people and information technologies. The course covers techniques and tools for carrying out literature reviews, forming research goals, designing research, conducting data analyses; and preparing manuscripts and live presentations. (Co-listed BUS 6887).

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## Materials Science & Eng (MS&E)

**MS&E 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MS&E 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MS&E 5010 Seminar** (RSD 0.0-6.0)

(Variable) Discussion of current topics.

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**MS&E 5040 Oral Examination** (IND 0.0)

(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D students may be processed during intercession. Off-campus M.S. students must be enrolled in an oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MS&E 5060 Chemistry of Construction Materials** (LEC 3.0)

The objective of the course is to utilize fundamental concepts of materials science and chemistry to understand, analyze, and describe the chemistry of construction materials. Special focus is given to describe composition-reactivity-microstructure-property relations in various cementitious materials. Prerequisites: At least Senior standing.

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**MS&E 5099 Research** (IND 0.0-15)

(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MS&E 5210 Tissue Engineering** (LEC 3.0)

The course will use problem-based case studies to introduce junior and senior undergraduate students to the principles and clinical applications of tissue engineering. Topics include the use of biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. Prerequisite: Junior or Senior standing. (Co-listed with Bio Sci 5240).

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**MS&E 5220 Advanced Phase Equilibria** (LEC 3.0)

Advanced aspects of unary, binary and ternary organic, phase equilibria. Includes practical examples of the applications of phase diagrams to solve engineering problems. Prerequisite: Graduate standing.

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**MS&E 5230 Energy Materials** (LEC 3.0)

The objectives of the course are to understand how the rational design and improvement of chemical and physical properties of materials can lead to energy alternatives that can compete with existing technologies. Discussions on the present and future energy needs from a view point of multidisciplinary scientific and technological approaches. Prerequisite: Senior standing.

**MS&E 5310 Biomaterials I** (LEC 3.0)

This course will introduce senior undergraduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. Prerequisites: Senior undergraduate standing. (Co-listed with BIO SCI 5210, CHEM ENG 5200).

**MS&E 5460 Molecular Engineering of Materials** (LEC 3.0)

This course focuses on the fundamentals of molecular engineering with an emphasis on their applications including renewable/clean energy solutions, energy storage, air/water cleaning, and optoelectronics. Topics include principles of modern physics, carbon chemistry, macromolecules, metal(covalent)-organic frameworks sol-gel processing and crystal growth. Prerequisites: Senior Standing or consent of instructor. (Co-listed with Chem 5460).

**MS&E 5517 Materials Selection in Mechanical Design** (LEC 3.0)

This course will introduce the basics of materials selection in mechanical design. It will also introduce the benefits of computational materials and process selection. The students will also learn to use a commercially available materials selection software. This course will be offered as Distance Ed. Prerequisite: Met Eng 2110.

**MS&E 5810 Introduction to Polymeric Materials** (LEC 3.0)

A basic study of the organic chemistry of natural and synthetic high polymers, their inherent properties and their uses in plastic, fiber, rubber, resin, food, paper and soap industries. Credit may not be given for both Chem 5810 and Chem 4810. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with Chem 5810).

**MS&E 5819 Polymer Synthesis and Characterization Lab** (LAB 1.0)

Laboratory experiments dealing with polymerization syntheses and solution, bulk and solid properties will be presented. Each student will prepare polymers and carry out all characterization experiments on actual samples. Credit may not be given for both Chem 5819 and Chem 4819. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810 or Chem Eng 5310, preceded or accompanied by Chem 1100 or Chem 5100 or an equivalent training program approved by S&T. (Co-listed with Chem 5819).

**MS&E 5850 Introduction to Coating Chemistry** (LEC 3.0)

Study of the basic principles of protective coatings with particular reference to the paint and varnish industry. Classifications, manufacture, properties and uses of protective coatings. Credit may not be given for both Chem 5850 and Chem 4850. Prerequisite: Chem 1320 or Met Eng 1210. (Co-listed with Chem 5850).

**MS&E 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MS&E 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MS&E 6010 Seminar** (RSD 0.0-6.0)

(Variable) Discussion of current topics.

**MS&E 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**MS&E 6060 Advanced Chemistry of Construction Materials** (LEC 3.0)

To describe fundamental composition-reactivity-microstructure-property relationships in construction materials. Tests will include quizzes, written-exams, as well as a term paper and a presentation on a topic relevant to the course.

**MS&E 6085 Internship** (IND 0.0-15)

(Variable) Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**MS&E 6099 Research** (IND 0.0-15)

(Variable) Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**MS&E 6110 Bonding, Crystallography, and Structure-Property Relationships** (LEC 3.0)

Principles of electronic structure and chemical bonding in solids and their relationships to electrical, mechanical, thermal, and optical properties. An exploration of reciprocal lattices and tensor properties of crystals; consideration of the impact of crystal symmetry on anisotropy. The influence of defects and grain boundary phenomena on material behavior. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

**MS&E 6120 Thermodynamics and Phase Equilibria** (LEC 3.0)

Classical thermodynamic treatment of materials and material processing based on the 1st and 2nd Laws of Thermodynamics and phase equilibria considerations. The course will cover equilibria in gaseous systems, gas-solid reactions including passive and active oxidation, solution thermodynamics, phase equilibria in solution systems, and electrochemistry. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

**MS&E 6130 Kinetic Theory for Materials** (LEC 3.0)

Phenomenological and atomistic theories of diffusion in materials including discussion of short circuit diffusion and ionic diffusion in an electric field. Fundamentals of phase transformation in materials; chemical fluctuation, nucleation and growth theory; kinetic models for evaluating and predicting diffusion controlled transformation kinetics. Prerequisite: Graduate standing, or undergraduate standing with instructor and advisor approval.

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**MS&E 6210 Advanced Tissue Engineering** (LEC 3.0)

The course will introduce graduate students to the principles and clinical applications of tissue engineering including the use biomaterials, scaffolds, cells, and external factors to develop implantable parts for the restoration, maintenance, or replacement of tissues and organs. A related topic term paper and oral presentation are expected. Prerequisite: Graduate standing. (Co-listed with Bio Sci 6240).

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**MS&E 6220 Advanced Energy Materials** (LEC 3.0)

The objectives of the graduate level course are to review the recent developments on advanced energy materials and systems in addition to basic understanding how chemical and physical properties of materials can lead to energy alternatives. Prerequisite: Graduate standing.

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**MS&E 6230 Nanomaterials** (LEC 3.0)

Introduction of the fundamentals of nanomaterials and recent developments on nanomaterials. Topics include physical and chemical properties, synthesis, processing, and applications of nanomaterials. Example nanomaterials include nanoparticles, nanotubes, and nanowires. Students will need to complete a project related to nanomaterials. Prerequisite: Graduate Standing. (Co-listed with Chem Eng 6310).

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**MS&E 6310 Biomaterials II** (LEC 3.0)

This course will introduce graduate students to a broad array of topics in biomaterials, including ceramic, metallic, and polymeric biomaterials for in vivo use, basic concepts related to cells and tissues, host reactions to biomaterials, biomaterials-tissue compatibility, and degradation of biomaterials. A term paper and oral presentation are required. (Co-listed with BIO SCI 6210, CHEM ENG 6300).

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**MS&E 6460 Advanced Molecular Engineering of Materials** (LEC 3.0)

This advanced course focuses on the fundamentals of molecular science and engineering and their applications including renewable/clean energy solutions, energy storage, and optoelectronics. Topics include principles of carbon chemistry, macromolecules, metal(covalent)-organic frameworks, sol-gel processing, crystal growth and other advanced topics. Prerequisites: Graduate Standing or consent of instructor. (Co-listed with CHEM 6460).

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**MS&E 6820 Polymer Synthesis** (LEC 3.0)

The methods of organic monomer and polymer syntheses will be explored. Mechanistic and structural components, modern and current industrial methods for polymer syntheses will be discussed. Topics include linear, branched, graft, and dendritic polymers, nano-technology and macromers. Prerequisites: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; Chem 2220 or Chem 4210 or Chem 4220 or Chem 5210 or Chem 5220. (Co-listed with Chem 6820).

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**MS&E 6840 Polymer Physical Chemistry and Analysis** (LEC 3.0)

A study of the physical properties of macromolecular systems including polymer solutions, gels, bulk polymers and rubbers. The chemical characterization of polymers based on their thermal, spectroscopic, microstructure and molecular weight is also discussed. Prerequisite: Chem 4810 or MS&E 4810 or Chem 5810 or MS&E 5810; thermodynamics. (Co-listed with Chem 6840).

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## Mathematics (MATH)

**MATH 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MATH 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MATH 5010 Graduate Seminar** (SEM 1.0)

Discussion of advanced or current topics.

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**MATH 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MATH 5099 Graduate Research** (IND 0.0-6.0)

Investigation of an advanced nature leading to the preparation of a MS thesis or dissertation.

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**MATH 5105 Modern Algebra I** (LEC 3.0)

Equivalence relations and functions, basic properties of groups, subgroups, permutations, cosets and Lagrange's Theorem, homomorphisms and isomorphisms, factor groups. Prerequisite: Math 3109 or graduate standing; preceded or accompanied by Math 3108.

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**MATH 5106 Modern Algebra II** (LEC 3.0)

This course is a continuation of Math 5105. Rings and fields are discussed. Euclidean domains, principal ideal domains, unique factorization domains, vector spaces, finite fields and field extensions are studied. Prerequisite: Math 5105.

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**MATH 5107 Combinatorics And Graph Theory** (LEC 3.0)

Covers some basics of enumeration and graph theory. Topics are selected from the following: permutations combinations, the inclusion/exclusion principle, generating functions, recurrence relations, trees, networks, graph connectivity and graph coloring. Prerequisite: Comp Sci 1200 or Math 3109.

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**MATH 5108 Linear Algebra II** (LEC 3.0)

Eigenvalue problems, Cayley-Hamilton theorem, Jordan normal form, linear functionals, bilinear forms, quadratic forms, orthogonal and unitary transformations, selected applications of linear algebra. Prerequisite: Math 3108.

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**MATH 5154 Mathematical Logic I** (LEC 3.0)

A mathematical introduction to logic with some applications. Functional and relational languages, satisfaction, soundness and completeness theorems, compactness theorems. Examples from Mathematics, Philosophy, Computer Science, and/or Computer Engineering.

Prerequisite: Philos 3254 or Math 5105 or Comp Sci 2500 or Comp Eng 2210. (Co-listed with Comp Eng 5803, Comp Sci 5203 and Philos 4354).

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**MATH 5215 Introduction To Real Analysis** (LEC 3.0)

Riemann-Stieltjes integration, sequences and series of functions, uniform approximation, the Banach Space  $C(a,b)$ , Lebesgue measure and integration, the space  $LP(a,b)$ , Fourier series. Prerequisite: Math 4209.

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**MATH 5222 Vector And Tensor Analysis** (LEC 3.0)

Vector algebra, vector differential and integral calculus, line and surface integrals, theorems of Stokes and Gauss, tensor algebra and tensor analysis, applications to problems in kinematics, elasticity theory, fluid mechanics, electromagnetic theory, relativity theory. Prerequisite: Math 2222; Math 3103 or Math 3108.

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**MATH 5302 Intermediate Differential Equations** (LEC 3.0)

Linear differential equations, vector-matrix systems, existence and uniqueness theory, nonlinear systems, phase-plane analysis, introduction to stability theory. Prerequisite: Math 3304 or Math 3329.

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**MATH 5325 Partial Differential Equations** (LEC 3.0)

Linear equations, heat equation, eigenfunction expansions, Green's formula, inhomogeneous problems, Fourier series, wave equation. Prerequisite: Math 3304 with a grade of "C" or better.

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**MATH 5351 Introduction To Complex Variables** (LEC 3.0)

The basic tools of complex variables are studied. These include the Cauchy-Riemann equations, complex contour integration, the Cauchy-Goursat theorem, conformal mappings, the calculus of residues and applications to boundary value problems. Prerequisite: Math 3304.

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**MATH 5483 Operational Calculus** (LEC 3.0)

The Laplace transformation, properties of the transformation, various applications to ordinary and partial differential equations, systems with step and Dirac functions as driving forces, various non-elementary functions and their transforms, problems in heat conduction and wave motion, Fourier transforms and their operational properties. Prerequisite: Math 3304.

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**MATH 5512 Introduction To Differential Geometry** (LEC 3.0)

Elements of the geometry of curves and surfaces in Euclidean three-space using methods of advanced calculus and vectors. Prerequisite: Math 4209 or Math 5222.

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**MATH 5530 Topics in Geometry - Graduate Option** (LEC 3.0)

A survey of non-Euclidean geometries, finite geometries, affine and projective planes, metric postulates for the Euclidean plane, and selected topics. Students will demonstrate graduate-level mastery of the subject matter. Credit will not be given for both Math 4530 and Math 5530. Prerequisites: MATH 3108.

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**MATH 5585 Introduction To Topology** (LEC 3.0)

Metric spaces; general topological spaces; connectedness, compactness, separation properties, functions and continuity. Prerequisite: Math 4209.

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**MATH 5603 Methods of Applied Mathematics** (LEC 3.0)

Methods to develop and analyze mathematical models. Topics include dimensional analysis and scaling, perturbation methods, and the construction of ordinary and partial differential equation models. Prerequisites: Math 3304 or 3329 with a grade of "C" or better, programming competency.

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**MATH 5604 Introduction to Numerical Methods for Differential Equations** (LEC 3.0)

An introduction to finite difference methods for ordinary and partial differential equations, including (1) the derivation of the numerical methods, (2) implementation of the methods in Matlab, and (3) the mathematical accuracy and stability analysis of the methods. Prerequisites: MATH 3304 and programming competency (preferably Matlab).

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**MATH 5737 Financial Mathematics** (LEC 3.0)

The course objective is to provide an understanding of the fundamental concepts of financial mathematics. Topics include pricing, assets-liability management, capital budgeting, valuing cash flow, bonds, futures, swaps, options. Preparation for the financial mathematics actuarial exam will be provided. Prerequisites: Math 1215 or Math 1221, Econ 1100 or Econ 1200, and one of the following: Stat 3111, Stat 3113, Stat 3115, Stat 3117 or Stat 5643. (Co-listed with Econ 5337).

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**MATH 5940 Mathematical Analysis For Secondary Teachers** (LEC 3.0)

Designed to help teachers gain a deeper understanding of the fundamental idea in analysis, that of a limit. A discovery method is used which includes both individual and group work. Students will present their results in written and oral format. Prerequisite: Math 2222 or equivalent.

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**MATH 5948 Mathematical Analysis For Secondary Teachers Practicum** (LEC 1.0)

An instructional unit based on the discovery method used in Math 340 will be designed by each student. These units will be class tested. The unit and results of class testing will be presented both in written and oral format. Prerequisite: Math 5940.

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**MATH 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MATH 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MATH 6010 Graduate Seminar** (RSD 1.0-3.0)

Discussion of topics of current interest. Prerequisite: Graduate standing.

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**MATH 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MATH 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MATH 6099 Research** (IND 0.0-15)

Investigation of an advanced nature leading to the preparation of a thesis or dissertation.

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**MATH 6105 Finite Fields And Applications** (LEC 3.0)

After reviewing basic group theory and introducing basic properties of commutative rings, the main focus of the course will be on topics such as structure of finite fields, polynomials over finite fields, and applications such as coding theory and cryptography. Prerequisite: Math 5105.

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**MATH 6106 Introduction to Ring Theory** (LEC 3.0)

Properties of rings with an emphasis on commutative rings. Ideals, factor rings, ring homomorphisms, polynomial rings; factorization, divisibility, and irreducibility. Introduction to extension fields and Galois theory. Applications may be chosen based on the interests of the students. Prerequisite: Math 5105.

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**MATH 6107 Group Theory** (LEC 3.0)

Groups, subgroups, and factor groups; homomorphisms, isomorphisms, and associated theorems; abelian groups; Sylow theorems and p-groups; permutation groups; free groups and generators; representation theory; cohomology theory. Prerequisite: Math 5106.

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**MATH 6108 Applied Matrix Theory** (LEC 3.0)

A second course in matrix theory directed toward applications. Linear spaces, linear operators, equivalence and similarity, spectral theorem, canonical forms, congruence, inertia theorem, quadratic forms, singular value decomposition and other factorizations, generalized inverses. Applications to optimization, differential equations, stability. Prerequisites: Math 3103, 3108, or 5302.

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**MATH 6215 Functions Of A Real Variable I** (LEC 3.0)

Measure spaces, extensions of measures, probability spaces, measures and distributions in normed linear spaces, product measures, independence, integral and expectation, convergence theorems, Radon-Nikodym theorem and applications. Lp spaces, selected topics. Prerequisite: Math 5215.

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**MATH 6216 Functions Of A Real Variable II** (LEC 3.0)

Abstract measures and integrals, the Daniell integration theory, integration on locally compact Hausdorff spaces, integration in function spaces, selected topics. Prerequisite: Must be preceded by Math 6215.

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**MATH 6330 Theory Of Differential Equations I** (LEC 3.0)

Stability theory, Liapunov's direct method, periodic solutions, Poincare-Bendixson theory, applications. Prerequisite: Math 5302.

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**MATH 6331 Theory Of Differential Equations II** (LEC 3.0)

Continuation of Math 6330. Nonlinear oscillations, solutions near singular points, asymptotic methods, differential equations on manifolds, boundary-value problems. Prerequisite: Math 5302.

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**MATH 6351 Functions Of A Complex Variable I** (LEC 3.0)

Complex plane, complex function theory, elementary Riemann surfaces, conformal mapping, complex integration, infinite complex series and sequences, calculus of residues with applications. Prerequisite: Math 4211.

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**MATH 6352 Functions Of A Complex Variable II** (LEC 3.0)

Argument principle and consequences; harmonic functions and Dirichlet's problem; infinite products; entire, meromorphic and rational functions; analytic continuation; symmetry principle; conformal mapping; functions of several complex variables. Prerequisite: Preceded by Math 6351.

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**MATH 6375 Theory Of Partial Differential Equations** (LEC 3.0)

Sobolev spaces; existence, uniqueness, and regularity of weak solutions to linear elliptic, parabolic, and hyperbolic PDEs; selected topics. Prerequisite: Math 6417.

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**MATH 6383 Special Functions** (LEC 3.0)

Infinite products, gamma and beta functions, asymptotic series, the hypergeometric function, generalized hypergeometric functions, Bessel functions, generating functions; polynomials of Legendre, Hermite, Laguerre, and Jacobi; elliptic functions, theta functions, Jacobian elliptic functions. Prerequisites: Math 4209 and 5351.

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**MATH 6417 Functional Analysis I** (LEC 3.0)

Banach spaces, Hilbert spaces, linear transformations, Hahn-Banach theorem, duality, uniform boundedness principle, weak topologies, convexity, bounded linear maps, compact operators, and spectral theory. Prerequisites: Math 5215; Math 5108 or Math 5585.

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**MATH 6418 Functional Analysis II** (LEC 3.0)

A continuation of Math 6417 with additional topics related to bounded and unbounded operators and their applications. Prerequisites: Math 6215 and Math 6417.

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**MATH 6461 Harmonic Analysis I** (LEC 3.0)

Fourier series, norm and pointwise convergence of Fourier series, the conjugate and maximal functions, analytic functions in the unit disk and Hardy spaces, interpolation of linear operators and the Hausdorff-Young-Riesz Theorem, Sidon sets. Prerequisites: Math 5215 and Math 5351.

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**MATH 6462 Harmonic Analysis II** (LEC 3.0)

Fourier integrals, almost-periodic functions on the real line, Banach algebras, Wiener's Tauberian Theorem and the prime number theorem, the Paley-Wiener Theorems, band-limited functions and Shannon's Theorem, the continuous wavelet transform, discrete wavelet transforms and frames, orthonormal bases of wavelets and multi-resolution analysis. Prerequisite: Must be preceded by Math 6461.

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**MATH 6540 Geometric Structures** (LEC 3.0)

Selected topics in non-Euclidean, solid, projective, and fractal geometry. Prerequisite: Math 4530.

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**MATH 6548 Geometric Structures Practicum** (LEC 1.0)

An instructional unit based on material learned in Math 6540 will be designed by each student. These units will be class tested. The unit and results of class testing will be presented both in written and oral format. Prerequisite: Math 6540.

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**MATH 6585 Topology I** (LEC 3.0)

Topological spaces, uniform and quasi-uniform spaces, product and quotient spaces, separation properties and connected spaces, compactness. Prerequisite: Math 5585.

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**MATH 6586 Topology II** (LEC 3.0)

Metrizability conditions, the theory of convergence using both filters and nets, completions and compactifications, and papers from the recent literature. Prerequisite: Math 6585.

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**MATH 6601 Numerical Analysis** (LEC 3.0)

A proof based course emphasizing theoretical analysis of convergence and accuracy of various numerical methods including approximate solutions of linear and nonlinear equations, numerical integration, and function approximation, with implementation to validate results and illustrate the methods. Prerequisites: Any 4000 or higher level MATH course, or any instructor approved 4000 or higher level course from another discipline with a significant computational component.

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**MATH 6602 Mathematical Foundation of Finite Element Methods** (LEC 3.0)

Implementation and theoretical analysis of the finite element method for the approximate solution of partial differential equations. Implementation of finite element methods for elliptic and parabolic equations. Theoretical analysis of convergence, accuracy, and stability of approximate solutions. Prerequisites: Any 4000 or higher level Mathematics course, or any instructor approved 4000 or higher level course from another discipline with a significant computational component.

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**MATH 6665 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Eng Mgt 6412 and Sys Eng 6412).

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**MATH 6737 Financial Mathematics II** (LEC 3.0)

Continuation of Math 5737/Econ 5337. Topics include martingales and measures, stopping times, discrete and continuous time finance, Brownian motion, Ito calculus, stochastic differential equations, Black-Scholes-Merton formula, numerical procedures. Prerequisite: Math 5737 or Econ 5337. (Co-listed with Econ 6337).

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**MATH 6802 Mathematical Physics I** (LEC 3.0)

Vector spaces, generalized coordinate transformations, vector analysis, tensors, partial differential equations in physics and boundary value problems, orthogonal functions and solutions to ordinary differential equations, hypergeometric, confluent hypergeometric, Legendre, Laguerre, and Bessel functions, Hermite polynomials, Green's functions in one dimension. (Co-listed with Physics 6403).

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**MATH 6803 Mathematical Physics II** (LEC 3.0)

Green's functions in three dimensions, integral equations, complex variable theory and contour integration, group theory with applications to quantum mechanics, solid state and molecular physics. Prerequisite: Math 6802 or Physics 6403. (Co-listed with Physics 6413).

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## Mechanical Engineering (MECH ENG)

**MECH ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MECH ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title. (Co-listed with Aero Eng 5001).

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**MECH ENG 5131 Intermediate Thermofluid Mechanics** (LEC 3.0)

Derivation of Navier-Stokes equations, analytical solutions of viscous flows; flow in pipes, flow networks; intermediate treatment of boundary layer theory; micro-fluidics and MEMS; introduction to numerical methods for solving fluid flows; and, preliminary treatise on turbulence. Prerequisite: Mech Eng 3131 or Aero Eng 3131. (Co-listed with Aero Eng 5131).

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**MECH ENG 5135 Fluid Machinery** (LEC 3.0)

Fundamental investigation of positive displacement and turbomachinery including pumps, fans, compressors, turbines, and oil hydraulic systems. Operating characteristics, selection, and comparison of types are studied. Prerequisite: Mech Eng 3131 or Aero Eng 5135.

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**MECH ENG 5139 Computational Fluid Dynamics** (LEC 3.0)

Introduction to the numerical solution of the Navier-Stokes equations, by finite difference methods, in both stream function-vorticity and primitive variable formulations. Course format emphasizes student development of complete computer programs utilizing a variety of solution methods. Prerequisites: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; one course in fluid mechanics. (Co-listed with Aero Eng 5139).

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**MECH ENG 5205 Lubrication** (LEC 3.0)

Development of basic principles of bearing analysis including manufacture and properties of lubricants, hydrodynamics and hydrostatic lubrication, journal and thrust bearings, ball and roller bearings, boundary considerations, and bearing materials. Prerequisite: Mech Eng 3131.

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**MECH ENG 5211 Introduction To Continuum Mechanics** (LEC 3.0)

Introductory cartesian tensor analysis to aid in the development of the theory of a continuum. Kinematics of deformation, stress tensor, equations of motion, equations of mass and energy balance. Examples from specific material theories in solid and fluid mechanics. Prerequisites: Civ Eng 2210, Math 3304.

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**MECH ENG 5212 Introduction to Finite Element Analysis** (LEC 3.0)

Variational formulation of the governing equations. Finite element model, interpolation functions, numerical integration, assembly of elements and solution procedures. Applications to solid mechanics, fluid mechanics and heat transfer problems. Two-dimensional problems. Computer implementation and use of commercial finite element codes. Prerequisites: Math 3304; senior or graduate standing. (Co-listed with Aero Eng 5212).

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**MECH ENG 5214 Applications Of Numerical Methods To Mechanics Problems** (LEC 3.0)

Numerical solutions of statics, vibrations, and stability problems. Direct stiffness formulations are developed and user-oriented computer codes are used to solve practical structures problems. Computer graphics techniques are utilized to prepare data and display results. Prerequisites: Civ Eng 2210; Mech Eng 2360 or Aero Eng 2360.

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**MECH ENG 5220 Advanced Mechanics of Materials** (LEC 3.0)

Comprehensive insight into mechanics of materials. Topics to include: theories of failure, torsion of noncircular sections, shear flow and shear center, unsymmetric bending, bending of curved members, beams on elastic foundation and pressurization of thick walled cylinders. Prerequisites: Civ Eng 2210, Math 3304. (Co-listed with Aero Eng 5220).

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**MECH ENG 5222 Introduction To Solid Mechanics** (LEC 3.0)

Review of basic concepts in continuum mechanics. Finite elasticity: some universal solutions for isotropic materials, application of special mechanical models. Linear elasticity: compatibility, stress functions, superposition, special examples such as extension, torsion, bending, and plane problems. Elements of plasticity. Prerequisite: Mech Eng 5211. (Co-listed with Aero Eng 5222).

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**MECH ENG 5229 Smart Materials And Sensors** (LAB 1.0 and LEC 2.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multi-disciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5229, Elec Eng 5270 and Civ Eng 5118).

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**MECH ENG 5234 Stability of Engineering Structures** (LEC 3.0)

Solution of stability problems with applications to columns, plates and shell structures. Torsional and lateral buckling of columns. Buckling under high temperatures. Effect of imperfections introduced by a technological process on stability. Design issues related to stability requirements. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Aero Eng 5234).

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**MECH ENG 5236 Fracture Mechanics** (LEC 3.0)

Linear elastic and plastic mathematical models for stresses around cracks; concepts of stress intensity; strain energy release rates; correlation of models with experiment; determination of plane stress and plane strain parameters; application to design. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5236).

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**MECH ENG 5238 Fatigue Analysis** (LEC 3.0)

The mechanism of fatigue, fatigue strength of metals, fracture mechanics, influence of stress conditions on fatigue strength, stress concentrations, surface treatment effects, corrosion fatigue and fretting corrosion, fatigue of joints, components and structures, design to prevent fatigue. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5238).

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**MECH ENG 5254 Variational Formulations Of Mechanics Problems** (LEC 3.0)

Introduction and study of variational problems in classical dynamics and solid mechanics emphasizing the concepts of virtual work, minimum potential energy, and complementary energy. Variational inequalities. Prerequisites: Civ Eng 2210; Math 3304; and Mech Eng 2350 or Mech Eng 2360 or Aero Eng 2360. (Co-listed with Eng Mech 354).

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**MECH ENG 5282 Introduction to Composite Materials & Structures** (LEC 3.0)

Introduction to fiber-reinforced composite materials and structures with emphasis on analysis and design. Composite micromechanics, lamination theory and failure criteria. Design procedures for structures made of composite materials. An overview of fabrication and experimental characterization. Prerequisite: Civ Eng 2210. (Co-listed with Aero Eng 5282).

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**MECH ENG 5283 Industrial Applications Of Composite Materials Technology** (LEC 3.0)

Composite materials-industrial applications. Fibers and matrices. Fabrication and NDI. Lamination theory overview. Composite joints. Postbuckling. Fatigue and environmental effects. Testing and certification of composite structures. A majority of the presentations will be made by engineers in the industry. Prerequisite: Civ Eng 2210. (Co-listed with Eng Mech 303).

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**MECH ENG 5307 Vibrations I** (LEC 3.0)

Equations of motion, free and forced vibration of single degree of freedom systems and multidegree of freedom systems. Natural frequencies, resonance, modes of vibration and energy dissipation are studied. The vibration of continuous systems is introduced. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Aero Eng 5307).

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**MECH ENG 5309 Engineering Acoustics I** (LEC 3.0)

Introduction to acoustical theory and measurement with emphasis on mechanical and aerospace engineering applications. Plane and spherical wave propagation, resonators and filters, absorption, room acoustics, human response to noise, noise legislation, noise control. Use of common instrumentation in several projects. Prerequisites: Mech Eng 3411 and 3313, or Aero Eng 3613 and Math 3304. (Co-listed with Aero Eng 5309).

**MECH ENG 5313 Intermediate Dynamics Of Mechanical And Aerospace Systems** (LEC 3.0)

Principles of dynamics are applied to problems in the design of mechanical and aerospace systems; basic concepts in kinematics and dynamics; dynamics of systems of particles; dynamics of rigid bodies, three-dimensional effects in machine elements; dynamic stability, theory and applications; methods of analytical dynamics. Prerequisite: Mech Eng 3313 or Aero Eng 3613. (Co-listed with Aero Eng 5313).

**MECH ENG 5420 Signal Processing for Instrumentation and Control** (LEC 3.0)

The course presents fundamental techniques for analysis and processing of experimental data and real-time signals. Continuous- and discrete-time development of signal spectra, Fourier Transform, convolution, filter design, and system identification. The emphasis is on practical problems that arise in instrumentation and control applications. Prerequisites: Math 3304; Mech Eng 3411 or permission of instructor for non-Mech Eng majors.

**MECH ENG 5449 Robotic Manipulators and Mechanisms** (LAB 1.0 and LEC 2.0)

Overview of industrial applications, manipulator systems and geometry. Manipulator kinematics; hand location, velocity and acceleration. Basic formulation of manipulator dynamics and control. Introduction to machine vision. Projects include robot programming, vision-aided inspection and guidance, and system integration. Prerequisites: Mech Eng 3313; Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972 or Comp Sci 1570. (Co-listed with Aero Eng 5449).

**MECH ENG 5478 Mechatronics** (LEC 2.0 and LAB 1.0)

This course will introduce students to the basics of mechatronics (i.e., the integration of mechanical, electrical, computer, and control systems). Students will learn the fundamentals of sensors and actuators for mechanical systems, computer interfacing, microcontrollers, real-time software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-listed with Aero Eng 5478, Elec Eng 5870 and Comp Eng 5820).

**MECH ENG 5481 Mechanical And Aerospace Control Systems** (LEC 3.0)

Synthesis of mechanical and aerospace systems to perform specific control functions. Response and stability are studied. Singular value analysis for stability margins is introduced. Prerequisite: Mech Eng 4479 or Aero Eng 3361. (Co-listed with Aero Eng 5481).

**MECH ENG 5519 Advanced Thermodynamics** (LEC 3.0)

After a short review of classical thermodynamics, the elements of chemical reactions, chemical equilibrium, statistical thermodynamics, and the basic concepts of kinetic theory are presented. Prerequisite: Mech Eng 2519. (Co-listed with Aero Eng 5519).

**MECH ENG 5523 Transport Phenomena In Manufacturing Processes** (LEC 3.0)

A study of the important role that transport phenomena (heat and mass transfer and fluid flow) play during various manufacturing processes including metal casting, joining and welding extrusion, forging, crystal growth, chemical deposition, and thermal spray deposition. Prerequisites: Mech Eng 3525 and 3131.

**MECH ENG 5525 Intermediate Heat Transfer** (LEC 3.0)

Analytical study of conduction; theory of thermal radiation and applications; energy and momentum equations in convective heat transfer and review of empirical relations. Current topics are included. Prerequisite: Mech Eng 3525. (Co-listed with Aero Eng 5525).

**MECH ENG 5527 Combustion Processes** (LEC 3.0)

Application of chemical, thermodynamic, and gas dynamic principles to the combustion of solid, liquid, and gaseous fuels. Includes stoichiometry, thermochemistry, reaction mechanism, reaction velocity, temperature levels, and combustion waves. Prerequisite: Mech Eng 3521. (Co-listed with Aero Eng 5527).

**MECH ENG 5533 Internal Combustion Engines** (LEC 3.0)

A course dealing primarily with spark ignition and compression ignition engines. Topics include: thermodynamics, air and fuel metering, emissions and their control, performance, fuels, and matching engine and load. Significant lecture material drawn from current publications. Prerequisite: Mech Eng 3521.

**MECH ENG 5537 Fuel Cell Principles** (LEC 3.0)

Fuel cell fundamentals including thermodynamics, reaction kinetics, mass transport, characterization, and modeling are discussed. Different types of fuel cells such as proton exchange membrane and solid oxide are covered together with subsystem design and system integration as well as environmental impacts. Prerequisites: MECH ENG 3521.

**MECH ENG 5541 Applied Energy Conversion** (LEC 3.0)

The study of the principles of energy conversion. Specific applications include fuel cells and other direct energy conversion devices used in plug-in hybrid electric vehicles. Prerequisite: Mech Eng 3521.

**MECH ENG 5543 Energy Efficiency of Vehicles** (LEC 3.0)

Course topics include the energy consumption, energy efficiency, pollution and carbon emissions of vehicles. Energy efficiency models are developed to illustrate how to optimize the energy efficiency of vehicles. Detailed models are developed for gasoline, diesel, electric and hybrid-electric cars and trucks. Prerequisites: Math 2222, Physics 2135.

**MECH ENG 5544 Non-Intrusive Measurement Methods** (LEC 3.0)

Fundamentals of non-contact measurement methods for engineers. Basic engineering optics with a focus on radiation measurement methods including the effects of various sources and detectors. Prerequisites: Phys 2135; Mech 3525 or consent of instructor for non-Mech Eng majors.

**MECH ENG 5566 Solar Energy Technology** (LEC 3.0)

Introduction to the nature of solar radiation and associated thermal energy transfers. Methods of collecting and storing solar energy. Analysis and design of systems for utilizing solar energy, including heating and cooling. Prerequisite: Mech Eng 3525, or consent of instructor for non-Mech Eng majors.

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**MECH ENG 5567 Heat Pump And Refrigeration Systems** (LEC 3.0)

The various methods used in the thermal design and analysis of both refrigeration and heat pumps systems are investigated. Various methods of producing heating and cooling are examined including vapor compression, absorption, air cycle, steam jet, and thermoelectric systems. Prerequisites: Mech Eng 3521, 3525.

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**MECH ENG 5570 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Nuc Eng 4370, Physics 4543).

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**MECH ENG 5571 Environmental Controls** (LEC 3.0)

Theory and applications of principles of heating, ventilating, and air conditioning equipment and systems; design problems. Physiological and psychological factors relating to environmental control. Prerequisites: Mech Eng 3521 and accompanied or preceded by Mech Eng 3525; or Mech Eng 2527 and Civ Eng 3330.

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**MECH ENG 5575 Mechanical Systems For Environmental Control** (LEC 3.0)

Analysis of refrigeration, heating, and air-distribution systems. Synthesis of environmental control systems. Prerequisites: Mech Eng 3521 and 3525; or Mech Eng 2527 and Civ Eng 3330.

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**MECH ENG 5606 Material Processing By High-Pressure Water Jet** (LEC 3.0)

Methods of generating high pressure water jets; standard equipment, existing techniques, and basic calculations. Application of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. Prerequisite: Mech Eng 3131 or undergraduate fluids course. (Co-listed with Min Eng 5413).

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**MECH ENG 5644 Interdisciplinary Problems In Manufacturing Automation** (LEC 2.0 and LAB 1.0)

The course will cover material necessary to design a product and the fixtures required to manufacture the product. Participants will gain experience with CAD/CAM software while carrying out an actual manufacturing design project. (Co-listed with Chem Eng 4310, Eng Mgt 5315).

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**MECH ENG 5653 Computer Numerical Control of Manufacturing Processes** (LEC 2.0 and LAB 1.0)

Fundamental theory and application of computer numerical controlled machine tools from the viewpoint of design principles, machine structural elements, control systems, and programming. Projects include manual and computer assisted part programming and machining. Prerequisites: Preceded or accompanied by Mech Eng 3653.

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**MECH ENG 5655 Manufacturing Equipment Automation** (LAB 1.0 and LEC 2.0)

Manufacturing automation at the equipment level. Topics include sensors, actuators, and computer interfacing for manufacturing equipment, dynamic modeling and control of manufacturing equipment, interpolation, coordinated motion control, kinematic and geometric error modeling, and runout. Prerequisites: Preceded or accompanied by Mech Eng 4479 or equivalent.

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**MECH ENG 5656 Design For Manufacture** (LEC 3.0)

Course covers the approach of concurrent product and process design. Topics includes: principle of DFM, New product design process, process capabilities and limitations, Taguchi method, tolerancing and system design, design for assembly and AI techniques for DFM. Prerequisites: Mech Eng 3708, Mech Eng 3653.

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**MECH ENG 5702 Synthesis Of Mechanisms** (LEC 3.0)

Synthesis of planar mechanisms for function generation, path generation, and motion generation. Emphasis is on analytical methods for synthesis. Prerequisite: Mech Eng 3313.

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**MECH ENG 5704 Compliant Mechanism Design** (LEC 3.0)

Introduction to compliant mechanisms; review of rigid-body mechanism analysis and synthesis methods; synthesis of planar mechanisms with force/energy constraints using graphical and analytical methods; pseudo-rigid-body models; force-deflection relationships; compliant mechanism synthesis methods; and special topics, e.g. bistable mechanisms, constant-force mechanisms, parallel mechanisms, and chain algorithm in design. Emphasis will be on applying the assimilated knowledge through a project on compliant mechanisms design. Prerequisites: Mech Eng 3313, Civ Eng 2210.

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**MECH ENG 5708 Rapid Product Design And Optimization** (LEC 3.0)

Product Life cycle design; Finding design solutions using optimization technique; Rapid product realization using rapid prototyping and virtual prototyping techniques. Prerequisite: Mech Eng 3708.

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**MECH ENG 5709 Machine Design II** (LEC 3.0)

A continuation of the study of machine elements; bearings, spur, bevel, worm, and helical gearing, and indeterminate machine elements; impact and shrink stresses. Prerequisite: Mech Eng 3708.

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**MECH ENG 5715 Concurrent Engineering** (LEC 3.0)

Students will be introduced to the concurrent engineering approach to product development. They will learn to set up quantitative requirements and then use a quantitative rating process to identify the critical requirements relating to the desired product. The interaction between design, manufacturing, assembly, cost, and supportability will be covered. The students will form teams and practice the concurrent engineering process for simple products. Prerequisites: Mech Eng 3313 or Aero Eng 3131, and Civ Eng 2210. (Co-listed with Aero Eng 5715).

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**MECH ENG 5757 Integrated Product And Process Design** (LEC 3.0)

Emphasize design policies of concurrent engineering and teamwork, and documenting of design process knowledge. Integration of product realization activities covering important aspects of a product life cycle such as "customer" needs analysis, concept generation, concept selection, product modeling, process development, and end of product life options. Prerequisites: Junior or above standing. (Co-listed with ENG MGT 5515).

**MECH ENG 5758 Integrated Product Development** (LEC 1.0 and LAB 2.0)

Students in design teams will simulate the industrial concurrent engineering development process. Areas covered will be design, manufacturing, assembly, process quality, cost, supply chain management, and product support. Students will produce a final engineering product at the end of the project. Prerequisite: Eng Mgt 5515 or Mech Eng 5757 or Mech Eng 3653 or Mech Eng 5708. (Co-listed with Eng Mgt 5516).

**MECH ENG 5760 Probabilistic Engineering Design** (LEC 3.0)

The course deals with uncertainties in engineering analysis and design at three levels - uncertainty modeling, uncertainty analysis, and design under uncertainty. It covers physics-based reliability analysis and reliability-based design, robustness assessment and robust design, their integration with design simulations, and their engineering applications. Prerequisite: Mech Eng 3708 or Aero Eng 3361. (Co-listed with Aero Eng 5760).

**MECH ENG 5761 Engineering Design Methodology** (LEC 3.0)

This course examines structured engineering design theory and methodologies for conceptual design and redesign of products. Topical coverage includes customer needs gathering, functional modeling, engineering specifications creation (OFD), concept generation, selection and design embodiment. Team work/hands-on projects emphasized. Prerequisite: At least Senior standing in engineering.

**MECH ENG 5763 Computer Aided Design: Theory and Practice** (LEC 2.0 and LAB 1.0)

Lectures cover the fundamentals of computer-aided design with emphasis on geometric modeling of curves, surfaces and solids, CAD/CAM data exchange, and computer graphics. In the lab session, students practice with commercial CAD/CAM systems including NX and SolidWorks to gain practical experience. Prerequisites: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; Mech Eng 2761; Math 2222; at least Junior standing.

**MECH ENG 5764 Introduction to Decision Analysis** (LEC 3.0)

This course is an introduction to decision analysis, a decision-making method under uncertainty. The course topics include probability theory, influence diagram, decision tree, subjective probability, sensitivity analysis, value of information, risk attitude, and utility models. Prerequisite: Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117.

**MECH ENG 5830 Applied Computational Methods** (LEC 3.0)

Detailed study of computational methods for efficient solution of selected fluids, structures, thermodynamics, and controls problems in aerospace and mechanical engineering. Besides basic numerical techniques, topics covered include gradient-based optimization and uncertainty quantification. Prerequisite: Comp Sci 1570 or Comp Sci 1970 or Comp Sci 1971 or Comp Sci 1972; Math 3304. (Co-listed with Aero Eng 5830).

**MECH ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

**MECH ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MECH ENG 6010 Seminar** (LEC 0.0-1.0)

Discussion of current topics. (Co-listed with Aero Eng 6010).

**MECH ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**MECH ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**MECH ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**MECH ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**MECH ENG 6123 Viscous Fluid Flow** (LEC 3.0)

Fundamentals of viscous fluids for incompressible and compressible flows governed by Navier-Stokes equations; exact, approximate, and numerical solutions for steady and unsteady laminar flows; boundary layer theory for incompressible and compressible flows; stability and transition. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Aero Eng 6123).

**MECH ENG 6131 Gas Dynamics I** (LEC 3.0)

A critical analysis of the phenomena governing the flow of a compressible fluid; introduction to flow in two and three dimensions; Prandtl-Meyer expansions; small perturbations in subsonic and supersonic flows; method of characteristics. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Aero Eng 6131).

**MECH ENG 6135 Turbulent Flows - Theory, Measurements and Modeling** (LEC 3.0)

Navier-Stokes equations; statistical description and mean-flow equations; behavior of free shear and wall bounded flows; the energy cascade; turbulence spectra and Kolmogorov hypothesis; measurement techniques: PIV, hot-wires, LDV; turbulence modeling for transport processes and closure schemes for RANS equations; evaluation of model constants, introduction to LES, DNS and hybrid-RANS. Prerequisite: Mech Eng 5131 or Aero Eng 5131 or Mech Eng 5139 or Aero Eng 5139 or equivalent. (Co-listed with Aero Eng 6135).

**MECH ENG 6137 Physical Gas Dynamics I** (LEC 3.0)

Features of high temperature gas flows including the development of the necessary background from kinetic theory, statistical mechanics, chemical thermodynamics and chemical kinetics. Equilibrium and non-equilibrium gas properties and gas flows are included. Prerequisite: Mech Eng or Aero Eng 5131. (Co-listed with Aero Eng 6137).

**MECH ENG 6212 Advanced Finite Element Analysis** (LEC 3.0)

Higher order, isoparametric and mixed finite elements. Eigenvalue and time-dependent problems. Solution procedures for dynamic analysis. Implicit and explicit methods. Applications to viscous incompressible fluid and plate bending problems. Three-dimensional problems. Nonlinear finite element analysis. Practical applications using commercial software. Prerequisite: Mech Eng 5212 or Aero Eng 5212. (Co-listed with Aero Eng 6212).

**MECH ENG 6222 Theory of Elasticity** (LEC 3.0)

Formulation and study of boundary-value problems in 2-D linear elastostatics: Equilibrium and compatibility. Stress function formulations in Cartesian and polar coordinates. Curved beam, wedge and plane contact problems. Dislocations and cracks. Thermoelasticity. Prerequisites: CIV ENG 2210. (Co-listed with Aero Eng 6222).

**MECH ENG 6230 Theory Of Plates** (LEC 3.0)

General coverage of various approaches to plate problems and the application of these methods to practical problems. Special topics include applications to elastic foundations, buckling and energy methods in plate theory. Prerequisite: Math 5325.

**MECH ENG 6232 Theory Of Shells** (LEC 3.0)

General theory of stress analysis of shells based on topics in differential geometry and general elasticity theory. Theory is applicable to studies of the elastic behavior of flat plates and shells, buckling and post-buckling behavior of shells, and provides a basis for all shell theories which account for anisotropy, plasticity, creep, thermal strains, internal reinforcements, and transverse shearing deformations. Prerequisite: Math 5325.

**MECH ENG 6236 Advanced Fracture Mechanics** (LEC 3.0)

Mathematical theories of equilibrium cracks and brittle fracture, mathematical analysis of elastic-plastic fracture mechanics, COD, R-curve and J-integral analysis. Prerequisite: Aero Eng 5236 or Mech Eng 5236.

**MECH ENG 6284 Analysis of Laminated Composite Structures** (LEC 3.0)

An overview of isotropic beams, plates, and shells. Bending, vibration, and buckling of laminated composite beams and plates: exact and approximate solutions. Development of composite shell theory and simplified solutions. Analysis of composite structures including transverse shear deformation and thermal effects. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Aero Eng 6284).

**MECH ENG 6285 Mechanics Of Composite Materials** (LEC 3.0)

Effective moduli of spherical, cylindrical, and lamellar systems. Micromechanics of fiber-matrix interfaces and unidirectional composites. Application of shear lag and other approximate theories to interfaces and composites including fiber pull-out, debonding and matrix cracking. Prerequisite: Mech Eng 5282 or Aero Eng 5282. (Co-listed with Aero Eng 6285).

**MECH ENG 6307 Advanced Vibrations** (LEC 3.0)

Advanced treatment of discrete and continuous vibratory systems. Extensive use is made of matrix methods and operator notation. Special topics include: transmission matrices, relative coordinates, time dependent boundary conditions, approximate techniques for linear systems, nonlinear systems, and random excitations. Prerequisite: Mech Eng or Aero Eng 5307. (Co-listed with Aero Eng 6307).

**MECH ENG 6309 Engineering Acoustics II** (LEC 3.0)

Expanded treatment of the theory of sound generation and propagation. The acoustic source, dipole, and quadrupole. Noise sources due to vibration and fluid flow. Sound propagation in the atmosphere. The transmission of sound in ducts. Propeller, fan, and jet noise. Prerequisite: Mech Eng or Aero Eng 5309. (Co-listed with Aero Eng 409).

**MECH ENG 6313 Advanced Dynamics Of Machinery** (LEC 3.0)

Current problems in aerospace dynamics are treated using methods of analytical mechanics; gyroscopic phenomena; the calculus of variations; stability of systems, to include approximate techniques. Prerequisite: Mech Eng or Aero Eng 5313. (Co-listed with Aero Eng 6313).

**MECH ENG 6447 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisite: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Eng Mgt 6410, Sys Eng 6217 and Comp Sci 6202).

**MECH ENG 6458 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Aero Eng 6458 and Sys Eng 6215).

**MECH ENG 6479 Analysis And Synthesis Of Mechanical And Aerospace Systems** (LEC 3.0)

A unified treatment of modern system theory for the Mechanical and Aerospace Engineering Controls Analyst, including analysis and synthesis of linear and nonlinear systems, compensation and optimization of continuous and discrete systems, and theory of adaptivity. Prerequisite: Mech Eng 5481 or Aero Eng 5481. (Co-listed with Aero Eng 6479).

**MECH ENG 6481 Advanced Topics in Decision and Control** (LEC 3.0)

This course will deal with latest topics in the areas of decision and control. Course may be repeated if topics vary. Prerequisite: Aero Eng 5481 or Mech Eng 5481 or equivalent. (Co-listed with Aero Eng 6481).

**MECH ENG 6525 Heat Transfer by Conduction** (LEC 3.0)

A study of conduction heat transfer in solids by analytical and other methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6525).

**MECH ENG 6526 Micro-/Nano-Scale Thermophysics and Energy Transport** (LEC 3.0)

Introduces advanced statistical thermodynamics, nonequilibrium thermodynamics, kinetic theory, and quantum theory to analyze thermophysics and energy transport for microscale and nanoscale systems. Covers the fundamental concepts of photons, electrons, and phonons in the forms of waves and particles. Includes applications to ultrafast laser processing. Prerequisite: Mech Eng 5525.

**MECH ENG 6527 Heat Transfer by Convection** (LEC 3.0)

An analytical study of convective heat transfer in laminar and turbulent flows; forced convection, natural convection, and mixed convection; combined heat and mass transfer; heat transfer with change of phase; instability of laminar flow; current topics in convection. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6527).

**MECH ENG 6529 Heat Transfer by Radiation** (LEC 3.0)

A study of the nature of thermal radiation; implications from electromagnetic theory; radiative characteristics of surfaces; enclosures; configuration factors; radiosity; specular and diffuse reflection; transfer in absorbing, emitting and scattering media; combined radiation conduction and convection; experimental methods. Prerequisite: Mech Eng or Aero Eng 5525. (Co-listed with Aero Eng 6529).

**MECH ENG 6541 Advanced Energy Conversion** (LEC 3.0)

An analytical study of power producing systems with emphasis on new techniques and energy sources. All basic methods of energy conversion are covered from detailed physical descriptions to mathematical analysis. Included are advanced heat engines, nuclear power reactors, thermoelectric engines, magnetohydrodynamic devices, solar energy, fuel cells, and recent developments. Prerequisite: Mech Eng (or Aero Eng) 5519, or Mech Eng (or Aero Eng) 5525.

**MECH ENG 6575 Advanced Environmental Control** (LEC 3.0)

The study of environmental control systems including their sizing, control, and energy requirements. Use of major energy analysis programs for system evaluation. Prerequisite: Mech Eng 5575.

**MECH ENG 6585 Advanced Optical Materials and Structures** (LEC 3.0)

Fundamental principles and advanced topics in optical materials and structures covering areas of photonics, plasmonics and metamaterials, and nanofabrication techniques. Prerequisite: Elec Eng 5200 or equivalent.

**MECH ENG 6653 Advanced Cnc Of Manufacturing Processes & Engineering Metrology** (LEC 2.0 and LAB 1.0)

Advanced treatment of Computer Numerical Control (CNC) part programming and machine tool metrology. Topics include mathematical modeling and characterization of machine tools and Coordinate Measuring Machines (CMMs); Measurement and analysis of dimensional accuracy, surface finish, precision, and uncertainty; Machine tool error modeling and compensation; Virtual Numerical Control (VNC) Machine Tool modeling, programming, simulation and process verification/ optimization. Projects include advanced CNC programming and simulation. Prerequisite: Mech Eng 5653.

**MECH ENG 6655 Modeling And Control Of Manufacturing Processes** (LEC 3.0)

This course covers control-oriented modeling, simulation, and control of manufacturing processes. Topics include digital control, control system hardware, servomechanisms, interpolation, coordinated motion control, regenerative chatter, and control of machining and non-traditional processes. Control algorithms are implemented on a machining center. Prerequisites: Mech Eng 5655, Mech Eng 5481.

**MECH ENG 6657 Laser Aided Manufacturing And Materials Processing** (LEC 3.0)

Fundamental studies in laser aided manufacturing and materials processing including laser principles and optics, physics of laser-materials interaction, interface responses for rapid solidification, theories on non-equilibrium synthesis, modeling of transport phenomena, optical sensing techniques, current topics and considerations for lasers in manufacturing. Prerequisite: Mech Eng 5525.

**MECH ENG 6659 Advanced Topics in Design and Manufacturing** (LEC 3.0)

Various topics in the area of design and manufacturing will be covered in this course: development of flexible manufacturing systems, CAD/CAM integration, rapid prototyping, etc. Prerequisites: Mech Eng 5655 or Mech Eng 5708 or equivalent.

**MECH ENG 6663 Advanced Digital Design and Manufacturing** (LEC 3.0)

This course covers freeform modeling, reverse engineering, numerical control path generation for material removal and addition, and virtual reality based digital design and manufacturing. Students learn theoretical and fundamental aspects of these topics from lectures and project exercises. Prerequisites: Mech Eng 5708 or Mech Eng 5757 or Mech Eng 5763 or equivalent.

**MECH ENG 6704 Mechanics of Machinery** (LEC 3.0)

Rigid-body kinematics, dynamics, and synthesis of mechanisms; cam-follower mechanisms; mathematical modeling of mechanisms containing elastic elements; transient and steady-state vibration response; parametric instability in elastic mechanisms; advanced topics in compliant mechanisms; high performance mechanisms will be emphasized. Prerequisites: Vector & matrix analysis; introductory planar kinematic & dynamic analysis of mechanisms; MECH ENG 5704 or equivalent.

**MECH ENG 6761 Modern Product Design** (LEC 3.0)

Modern product development, design and prototyping are examined from a product architecture standpoint in this course. Functional modeling techniques are used to establish the architecture of a product and recently developed theories and techniques for design are covered. A prototyping project is required to provide immediate application of the theories. Prerequisite: Aero Eng 5758 /Eng Mgt 4312 or Mech Eng 5708 or Mech Eng 5656.

## Metallurgical Engineering (MET ENG)

**MET ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**MET ENG 5001 Graduate Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MET ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**MET ENG 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**MET ENG 5110 High Temperature And Corrosion Resistant Alloys** (LEC 3.0)

Fabrication and use of nickel, titanium, and refractory metal based alloys for use at high temperatures or in chemically corrosive environments. Properties and strengthening mechanisms of these alloys. Theory of high temperature oxidation and corrosion and design of alloys to prevent them. Prerequisites: Met Eng 3130, 2125.

**MET ENG 5150 Introduction to Metal Additive Manufacturing** (LEC 3.0)

Metal and alloys associated with Additive Manufacturing (AM). Issues with powders and wires as starting materials, safety, solidification mechanisms and development of microstructure and defects, AM part performance, and mechanical properties. Current alloys being utilized and future materials being developed. Prerequisite: Met Eng 2110.

**MET ENG 5160 Mechanical Metallurgy** (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication. Prerequisites: Met Eng 3120, 3125, Civ Eng 2210.

**MET ENG 5170 Nuclear Materials I** (LEC 3.0)

Fundamentals of materials selection for components in nuclear applications. Design and fabrication of UO<sub>2</sub> fuel; reactor fuel element performance; mechanical properties of UO<sub>2</sub>; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110.(Co-listed with Nuc Eng 4241).

**MET ENG 5171 Nuclear Materials II** (LEC 3.0)

Extractive metallurgy of uranium, thorium, and zirconium. Equation of state of UO<sub>2</sub> and fuel chemistry. LMFBR fuel and interaction of sodium and stainless steel. Materials for fusion and other advanced nuclear applications. Reprocessing of spent fuel and disposal. Prerequisite: Met Eng 5170.

**MET ENG 5220 Recent Advances In Extractive Metallurgy** (LEC 2.0)

A survey of extractive processes recently developed in the light of modern requirements with respect to raw materials, product quality, environmental impact, energy consumption, capital cost and process control. Prerequisite: Met Eng 4350.

**MET ENG 5270 Mineral Processing II (Mechanics and Design)** (LAB 1.0 and LEC 2.0)

Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisite: Min Eng 3412. (Co-listed with Min Eng 5424).

**MET ENG 5310 Corrosion and Its Prevention** (LEC 3.0)

A study of the theories of corrosion and its application to corrosion and its prevention. Prerequisite: A grade of "C" or better in either Chem Eng 3120 or Cer Eng 3230. (Co-listed with Chem Eng 5315).

**MET ENG 5330 Nonferrous Alloys** (LEC 3.0)

Structure and properties of nonferrous alloys (Al, Ti, Mg, Ni and Cu) are described. The role of processing and microstructure in the development of mechanical properties is emphasized. Prerequisite: Met Eng 3130 or Met Eng 5810.

**MET ENG 5420 Advanced Metals Casting** (LEC 3.0)

An advanced course in the materials and methods used in modern metals casting processes. Application of metallurgical principles to the casting of metals. Design of castings and metals casting mold features using commercial casting process simulation software. Prerequisite: Met Eng 3420 or Mech Eng 2653.

**MET ENG 5425 Metals Casting Laboratory** (LAB 1.0)

An advanced laboratory study of mold materials, metal flow, and cast metals. Emphasis is given to design of gating, risering, and ladle treatment techniques required for economical, highquality castings. Prerequisite: Accompanied or preceded by Met Eng 4420.



**MET ENG 5430 Metals Joining** (LEC 2.0)

Metals joining processes such as welding and brazing. Effects of welding on materials. Treatment and properties of welded joints. Welding defects and quality control. Prerequisite: Met Eng 2110 or 3420.

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**MET ENG 5440 Metal Deformation Processes** (LEC 3.0)

An introduction to metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisite: Met Eng 3120 and Met Eng 3420 both with "C" or better grade.

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**MET ENG 5450 Advanced Steelmaking** (LEC 3.0)

This course is designed to provide students with an enhanced understanding of the chemistry and physics of ironmaking, steelmaking and casting, to apply these concepts to a wide range of problems in modern steelmaking and casting operations, and to perform advanced design and operational calculations associated with refining and continuous casting processes. Prerequisite: Grade of "C" or better in Cer Eng 3230 or Met Eng 3330.

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**MET ENG 5460 Metal Coating Processes** (LEC 3.0)

Introduction to the current technologies used to enhance metal performance, particularly corrosion resistance, by overlay coatings. Deposition processes are emphasized and the fundamentals of the behavior of the films in high technology and electronic materials applications is discussed. Prerequisite: Senior or Graduate Standing.

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**MET ENG 5470 Ferrous Metals Casting** (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment. Prerequisite: Met Eng 4420 or Met Eng 5420 or graduate standing with permission of instructor.

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**MET ENG 5480 Refining Of Metals** (IND 2.0-3.0)

Principles and applications of refined metal production by electrochemical methods. The course will address basic copper and zinc processing, electrometallurgy, anodes and anodic processes, cathode deposit control and contamination mechanisms, Faraday's Law and current efficiency, and current state of practice. Prerequisite: Cer Eng 3230 and Met Eng 3220 or graduate standing.

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**MET ENG 5510 Nondestructive Testing** (LEC 3.0)

Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Elec Eng 5670).

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**MET ENG 5515 Nondestructive Testing Laboratory** (LAB 1.0)

Application of radiological and ultrasonic methods of nondestructive testing of metallic materials. A radiographic X-ray units and ultrasonic equipment are used in the inspection of a variety of materials and manufactured parts. Prerequisite: Accompanied or preceded by Met Eng 5510.

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**MET ENG 5520 Electron Microscopy** (LEC 3.0)

A course in the theory and application of both scanning and transmission electron microscopy and x-ray microanalysis. Topics considered are electron optics, image formation and analysis; x-ray generation, detection and analysis; and characterization of fracture surfaces. Prerequisites: Met Eng 3130 and Met Eng 2125, or a course in optical microscopy.

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**MET ENG 5525 Scanning Electron Microscopy Lab** (LAB 1.0)

A course in the practical use and operation of scanning electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

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**MET ENG 5620 Materials Behavior** (LEC 3.0)

A course in crystal defects and deformation; mechanical testing; creep; fracture mechanics and fatigue. Prerequisites: Grade of "C" or better in both Met Eng 2110 and Met Eng 3120.

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**MET ENG 5630 Environmental Aspects Of Metals Manufacturing** (LEC 3.0)

Introduction to environmental aspects of metal extraction, melting, casting, forming, and finishing. Subjects include history of environmental movement and regulations permitting, risk analysis, disposal and recycling of metal manufacturing residues, environmental ethics, environmental technologies and case studies. Prerequisite: Junior/Senior standing.

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**MET ENG 5810 Principles Of Engineering Materials** (LEC 3.0)

Examination of engineering materials with emphasis on selection and application of materials in industry. Particular attention is given to properties and applications of materials in extreme temperature and chemical environments. A discipline specific design project is required. (Not a technical elective for undergraduate metallurgy or ceramic majors) (Co-listed with Aero Eng 3877, Chem Eng 5300, Physics 4523, Cer Eng 5810).

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**MET ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MET ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MET ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MET ENG 6160 Advanced Mechanical Metallurgy** (LEC 3.0)

Elastic and plastic behavior of metallic single crystals and polycrystalline aggregates. Resulting changes in mechanical properties are considered. Included are applications to metal fabrication.

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**MET ENG 6320 Advanced Steels and Their Treatment** (LEC 3.0)

Industrially important ferrous alloys are described and classified. The selection of proper heat treatments to facilitate fabrication and to yield required service properties in steels suitable for various applications is considered. Prerequisites: Met Eng 3130 and Met Eng 2125.

**MET ENG 6325 Advanced Ferrous Microstructures** (LAB 1.0 and LEC 1.0)

Course provides an in-depth explanation of microstructural development during solidification, thermo-mechanical processing, and heat treatment of steel. Topics: microscopy, metallography, the Fe-C phase diagram, solidification, homogenization, grain size control, formation of microstructures upon heating/cooling. Term paper and presentation required.

**MET ENG 6440 Advanced Metal Deformation Processes** (LEC 3.0)

Advanced metal deformation concepts followed by a study of various forming processes from both the analytical and applied viewpoints. Processes to include: forging, wire drawing, extrusion, rolling, sheet metal forming, and others. Prerequisites: A grade of "C" or better in both Met Eng 3120 and Met Eng 3420.

**MET ENG 6470 Advanced Ferrous Metals Casting** (LEC 3.0)

An advanced study of the metallurgy of cast irons and net shape cast steel alloys. Includes theories of nucleation and growth in gray, nodular, compacted graphite and malleable irons. The effects of deoxidation practice and inclusion shape control for cast steels are also included. The effects of alloying elements, processing variables and heat treatment.

**MET ENG 6535 Transmission Electron Microscopy Lab** (LAB 1.0)

A course in the practical use and operation of transmission electron beam instruments and their associated techniques. Prerequisite: Preceded or accompanied by Met Eng 5520.

## Mining Engineering (MIN ENG)

**MIN ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

**MIN ENG 5001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**MIN ENG 5113 Mine Atmosphere Control** (LAB 1.0 and LEC 2.0)

Fundamentals of mine ventilation, including the principles of airflow, control of gases, dust, and temperature, methane drainage, mine fans, network theory, computer network simulation, and economics of airflow, with emphasis on analysis, systems design and practical application. Prerequisite: Mech Eng 2527 and Civ Eng 3330; or Nuc Eng 3221.

**MIN ENG 5212 Aggregates and Quarrying** (LEC 3.0)

Advanced coverage of topics on the stone and aggregate industry, including surface and underground operations, plant equipment, economics, marketing, transportation, and environmental topics. The course will include at least one field trip and a design project. Prerequisite: Min Eng 3912; Preceded or accompanied by Civ Eng 3116.

**MIN ENG 5322 Coal Mining Methods** (LEC 3.0)

An in-depth study of all aspects of coal mining, including an overview of the coal industry, reserves and geology, planning and development of coal mines, surface and underground mechanized methods of face preparation, equipment, coal extraction, handling and preparation as practiced in the United States. Prerequisites: Min Eng 5912.

**MIN ENG 5412 Aggregates Materials Sizing and Characterization** (LAB 1.0 and LEC 2.0)

Geological formation of aggregates; aggregate properties and their measurements; aggregates for specific end-user applications; specifications and standards; processing (crushing, screening, classification, and washing); plant design and flow sheet analysis; quality control and assurance. Field trip to a nearby quarry required. Prerequisite: Min Eng 2412.

**MIN ENG 5413 Material Processing by High Pressure Water Jet** (LEC 3.0)

Methods of generating high pressure water jets; standard equipment, existing techniques and basic calculations. Applications of water jets to materials cutting and mineral processing. Safety rules. The course will be supported by laboratory demonstrations. (Co-listed with Mech Eng 5606).

**MIN ENG 5422 Coal Preparation** (LEC 2.0 and LAB 1.0)

Coal properties, sampling, testing, breaking, sizing, cleaning and dewatering. Disposal of refuse. Prerequisite: Min Eng 2412.

**MIN ENG 5423 Flotation and Hydrometallurgy** (LEC 2.0 and LAB 1.0)

Forth flotation including mineral surfaces, double layer theory, zeta potential, hydrophobicity, adsorption, collectors, frothers, modulation, kinetics, and sulphide and acid flotation systems. Hydrometallurgy including leaching, ion exchange and liquid/liquid extraction. Prerequisites: Min Eng 2412.

**MIN ENG 5424 Mineral Processing II Mechanics And Design** (LEC 2.0 and LAB 1.0)

Mineral particle mechanics of comminution, sizing, classification, concentration, filtering and thickening. Mill and equipment selection and design including flowsheet, development and plant assessment. Prerequisites: Min Eng 2412. (Co-listed with Met Eng 5270).

**MIN ENG 5522 Ore Reserve Analysis and Geostatistics** (LAB 1.0 and LEC 2.0)

Principles of geostatistics, theory of spatially correlated random variables, variance and co-variances and their application on the evaluation of mineral resources, ore reserve estimation, strategic exploration, and production planning. Real case studies from mining industry will be presented. Prerequisites: Math 3304; Stat 3113 or Stat 3115.

**MIN ENG 5532 Advanced Mining Economics** (LEC 3.0)

Mining industry & national economics. Social & economics significance of mined commodities. Marketing of mined commodities. Innovation approaches to mine financing, project loans, and leasing. Mining feasibility studies, government influence & policy, mining industry foreign investment, investment strategies, mining taxation, cost predictions. Case Studies.

**MIN ENG 5612 Principles of Explosives Engineering** (LAB 1.0 and LEC 2.0)

Theory and application of explosives in the mining industry; explosives, initiating systems, characteristics of explosive reactions and rock breakage, fundamentals of blast design, drilling and blasting, regulatory and safety considerations. Prerequisites: Min Eng 2126; successful background check. (Co-listed with Exp Eng 5612).

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**MIN ENG 5622 Blasting Design And Technology** (LAB 1.0 and LEC 2.0)

Advanced theory and application of explosives in excavation; detailed underground blast design; specialized blasting including blast casting, construction and pre-splitting. Introduction to blasting research. Examination of field applications. Prerequisites: Min Eng 5612. Student must be at least 21 years of age. Successful background check. (Co-listed with Exp Eng 5622).

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**MIN ENG 5742 Environmental Aspects of Mining** (LEC 3.0)

Permitting: the legal environment of reclamation and environmental impact assessment; post-mining land-use selection and mine planning for optimum reclamation of all mines: metal, nonmetal, and coal; unit operations of reclamation: drainage, backfill, soil replacement, revegetation, maintenance, etc. Prerequisites: Preceded or accompanied by Min Eng 5933 or Geo Eng 5441 or Env Eng 5619. (Co-listed with Geo Eng 5276).

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**MIN ENG 5822 Strata Control** (LEC 3.0)

A detailed review of artificial ground support, both above and below ground, including slope stabilization techniques and shaft and tunnel liner design. The use of shotcrete, roofbolts, and solid liners and the principles of underground longwall and room and pillar mine support. Longwall and hydraulic mining practice is covered. Prerequisite: Min Eng 4823.

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**MIN ENG 5823 Rock Mechanics** (LEC 2.0 and LAB 1.0)

Applications of the fundamental principles of mechanics to engineering problems of equilibrium, strength and stiffness of rock materials. Review of in-situ stresses, laboratory and field instrumentation, rock and rockmass properties. Ground Control; pillar design, roof span design, rock reinforcement, surface subsidence, slope stability, and violent failure. Prerequisites: Physics 2135; Civ Eng 2210; Geology 3310. Field trip required.

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**MIN ENG 5912 Mine Power and Drainage** (LEC 2.0 and LAB 1.0)

Engineering principles of mine power distribution and application and mine dewatering. Basics of electrical circuits, AC/DC power, transformers, electric meters, power distribution, and power management. Hydraulic power systems. Compressed air in mines. Mine dewatering. Controlling water inflow. Dewatering wells. Water pumping and pumping systems. Prerequisite: Mech Eng 2527 and Civ Eng 3330; or Nuc Eng 3221.

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**MIN ENG 5913 Advanced Computer Aided Mine Design** (LEC 2.0 and LAB 1.0)

Project-based mine planning and design course. Engineering design process applied to computer-aided mine planning and design. Mine layouts, production planning, and materials scheduling optimization. Prerequisite: Graduate standing.

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**MIN ENG 5922 Tunneling & Underground Construction Techniques** (LEC 2.0 and LAB 1.0)

Mechanical and conventional excavation techniques in underground tunneling and construction. Topics include tunneling layouts design, equipment and performance modeling, ground control systems including support, drainage, and structural integrity. Construction specifications, advance rate and contractual and cost estimation. Prerequisite: Consent of instructor. (Co-listed with Exp Eng 5922).

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**MIN ENG 5932 Underground Mining Methods** (LEC 3.0)

Principles of planning, constructing, and operating economically viable underground mines. Cost effective mining methods: room-and-pillar, sublevel open stoping, VCR, shrinkage, sublevel caving, cut-and-fill, block caving, longwall. Selection of equipment for underground mining operations. Optimization of mine performance. Field trip Required. Prerequisite: Preceded or accompanied by Min Eng 3913.

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**MIN ENG 5933 Surface Mining Methods** (LEC 3.0)

Principles of planning, constructing, and operating economically viable surface mines. Cost effective mining methods: placer mining, strip mining, open pit mining, quarrying. Selection of equipment for surface mining operations. Optimization of mine performance. Field trip required. Prerequisites: Min Eng 3912; Min Eng 3512; preceded or accompanied by Min Eng 5823.

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**MIN ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**MIN ENG 6001 Special Topics** (LAB 1.0 and LEC 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**MIN ENG 6010 Seminar** (RSD 1.0)

Discussion of current topics.

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**MIN ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**MIN ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**MIN ENG 6080 Graduate Project** (IND 3.0)

Advanced engineering design, experimentation, evaluation and assessment leading to the preparation of a project report. For practicing professionals, this project could be based on an actual industry problem. Prerequisites: Graduate Standing.

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**MIN ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**MIN ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**MIN ENG 6132 Advanced Mine Health And Safety Design** (LEC 3.0)

Principles of design of mining operations with emphasis on the health and safety of the worker. Prerequisite: Graduate standing.

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**MIN ENG 6133 Mine Atmospheric Control II** (LEC 3.0)

Climatic measurements and temperature precalculations, emergency plans for fan failures and mine fires, mine air contaminants, mine noises, mine dust, refrigeration and cooling plant layout, radiation control. Prerequisite: Min Eng 4113.

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**MIN ENG 6432 Advanced Mineral Engineering Design II** (LEC 1.0 and LAB 2.0)

Incorporation of principles developed in Min Eng 6132 in advanced design projects for mineral plants and systems, with emphasis on environmental protection, health, and safety. Prerequisite: Min Eng 6132.

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**MIN ENG 6522 Mining Property Feasibility Studies And Evaluation Procedure** (LAB 1.0 and LEC 2.0)

A systematic phased approach is presented, designed to increase the level of confidence and accuracy of estimates, moving from exploration through to a "bankable" study. Liability, ethics, resource/reserves, political/social/investment risk, economic parameters, and due diligence are discussed. Prerequisite: Min Eng 3512 or Geology 3511 or Min Eng 4742 or Geophys 3251.

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**MIN ENG 6532 Mine Management II** (LEC 3.0)

The course covers advanced concepts in managing mine operations. Topics to be covered include TQM, statistical process control, benchmarking, KPI, standards and standardization, ISO 9000: Quality Control, ISO 14000: Environmental systems, OHSAS 18000. Management systems, SA8000, Social Accountability and others. Prerequisite: Consent of instructor.

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**MIN ENG 6622 Environmental Controls For Blasting** (LAB 1.0 and LEC 2.0)

Advanced blast mechanics; overbreak control including comprehensive coverage of perimeter and smoothwall specialist blasting techniques and geotechnical factors affecting blast vibration, limits analysis monitoring and control; air blast control including limits, monitoring and atmospheric and topographic effects. Prerequisites: Min Eng 5612, Successful background check. (Co-listed with Exp Eng 6412).

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**MIN ENG 6632 Theory Of High Explosives** (LEC 3.0)

Study of the application of chemical thermodynamics and the hydrodynamic theory to determine the properties of high explosives; application of detonation theory to steady-state detonations in real explosives; application of the above to the blasting action of explosives. Prerequisite: Graduate Standing. (Co-listed with Exp Eng 6212).

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**MIN ENG 6712 Managing Social and Environmental Risks in Mining (Intro to Responsible Mining)** (LEC 3.0)

This course is an introduction to responsible mining. It focuses on industry and NGO programs around sustainability and reporting in mining, financial community response, community of interest engagement and participation, and safety and crisis response and management. Prerequisites: Min Eng 4742 or Min Eng 5742.

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**MIN ENG 6735 Sustainability In Mining** (LEC 3.0)

Sustainability defined: social, economic and environmental impacts. Mining as sustainable development interventions. Mine planning for sustainability, sustainability assessment and reporting, sustainable mine closure and post-mining land use. Case studies. Prerequisite: Min Eng 4742.

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**MIN ENG 6842 Advanced Rock Mechanics** (LEC 3.0)

Advanced topics in static and dynamic rock mechanics; elasticity theory, failure theories and fracture mechanics applied to rock; stress wave propagation and dynamic elastic constants; rock mass classification methods for support design; pillar design in coal and metal mines; introduction to numerical models. Prerequisite: Min Eng 5823 or Civ Eng 3715.

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**MIN ENG 6843 Dynamic Rock Mechanics** (LEC 3.0)

Advanced topics in dynamic rock mechanics. Stress wave propagation in the earth, dynamic elastic constants in isotropic and anisotropic rock, Hopkinson bar impact analysis, spallation and radial fracturing caused by stress pulses, shock wave generation in rock by explosives, shock wave propagation and effects. Prerequisite: Min Eng 5823 or Civ Eng 3715.

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**MIN ENG 6912 Simulation of Mining Systems** (LEC 3.0)

Overview of stochastic simulation. Model formulation using general purpose process simulation software. Model verification and validation. Simulation experimentation. Prerequisites: Graduate standing or Stat 5643.

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**MIN ENG 6922 Optimization Applications In Mining I** (LEC 3.0)

Mining applications of deterministic optimization techniques are covered, including linear, integer, mixed-integer, dynamic, unconstrained and constrained nonlinear, and heuristic programming. Prerequisite: Graduate standing or consent.

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**MIN ENG 6923 Geostatistics** (LEC 3.0)

Definition of geostatistical data; theory of random fields; autocorrelation and measures of spatial variability including semivariograms, variograms and covariance functions; and spatial prediction and validation. Case studies in mineral resource estimation and environmental pollutant prediction will be presented. Prerequisites: Graduate standing or consent of instructor.

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**MIN ENG 6932 Advanced Mining Systems** (LEC 3.0)

Principles of design for the development and production of hard rock mineral deposits that require integrated surface and underground mining methods. Cost considerations leading to optimization. Terminal feasibility report required. Prerequisites: Min Eng 4932 and Min Eng 4933.

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**MIN ENG 6935 Underground Mine Design** (LEC 3.0)

This course will focus on the determinants of underground mine design, geomechanical mine design for underground mining; mine optimization; mine environmental systems; and underground mine design and optimization. Prerequisite: Min Eng 4932 or equivalent.

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**MIN ENG 6936 Surface Mine Design** (LEC 3.0)

This course will focus on the determinants of surface mine design, geomechanical and geometrical mine design for open pit and strip mining; mine layouts optimization; mine environmental systems; and research directions in surface mine design and optimization. Prerequisite: Min Eng 4933 or equivalent.

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**MIN ENG 6992 Research Methods** (LEC 3.0)

Foundations, dimensions, and methods for designing and investigating research problems. Focus on fundamentals and applied research, research methods, literature review, experimental design and experimentation, dissertation composition, concepts of originality and intellectual property. Prerequisites: PhD students only. (Co-listed with Exp Eng 6292).

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## Nuclear Engineering (NUC ENG)

**NUC ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**NUC ENG 5001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**NUC ENG 5203 Reactor Physics I** (LEC 3.0)

Study of neutron interactions, fission, chain reactions, neutron diffusion and neutron slowing down; criticality of a bare thermal homogeneous reactor. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5207 Nuclear Fuel Cycle** (LEC 3.0)

Nuclear fuel reserves and resources; milling, conversion, and enrichment; fuel fabrication; in-and-out-of core fuel management; transportation, storage, and disposal of nuclear fuel; low level and high level waste management; economics of the nuclear fuel cycle. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5241 Nuclear Materials I** (LEC 3.0)

Fundamentals of materials selection for components in nuclear applications; design and fabrication of UO<sub>2</sub> fuel; reactor fuel element performance; mechanical properties of UO<sub>2</sub>; radiation damage and effects, including computer modeling; corrosion of materials in nuclear reactor systems. Prerequisites: Civ Eng 2210; Nuc Eng 3205; Nuc Eng 3223; Met Eng 2110. (Co-listed with Met Eng 5170).

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**NUC ENG 5251 Reactor Kinetics** (LEC 3.0)

Derivation and solutions to elementary kinetics models. Application of the point kinetics model in fast and thermal reactor dynamics, internal and external feedback mechanisms, rigorous derivation and solutions of the space dependent kinetics model fission product and fuel isotope changes during reactor operation. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5257 Introduction to Nuclear Thermal Hydraulics** (LEC 3.0)

An introductory course in the application of thermal-hydraulic principles to energy systems, with emphasis on nuclear energy issues. Will include the development of constitutive models and applications to power systems, fluid mechanics, and heat transfer problems (including multiphase flows). Prerequisite: Graduate standing.

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**NUC ENG 5281 Probabilistic Risk Assessment I** (LEC 3.0)

A study of the techniques for qualitative and quantitative assessment of reliability, safety and risk associated with complex systems such as those encountered in the nuclear power industry. Emphasis is placed on fault tree analysis. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5312 Nuclear Radiation Measurements and Spectroscopy** (LAB 1.0 and LEC 2.0)

Contemporary radiation detection theory and experiments with high resolution gamma-ray spectroscopy, solid state detectors, neutron detection and conventional gas filled detectors. Neutron activation analysis of unknown material, statistical aspects of nuclear measurements. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5347 Radiological Engineering** (LEC 3.0)

Radiation exposure pathways analysis. Modeling of radionuclides transport through atmosphere, surface and ground water. Human health impact. Transportation of nuclear waste. Nuclear Waste characterization. Regulatory structure and requirements. Scenario case studies and computer simulation of transport. Prerequisite: Nuc Eng 3205.

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**NUC ENG 5350 Advanced Nuclear Medical Science** (LEC 3.0)

Advanced level of technologies involved in medical modalities, such as digital radiography, digital mammography, modern computed tomography, gamma camera, SPECT and PET will be covered. Prerequisites: Nuc Eng 4312 or equivalent.

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**NUC ENG 5363 Applied Health Physics** (LEC 3.0)

Radiation sources; external and internal dosimetry; biological effects of radiation; radiation protection principles; regulatory guides; radioactive and nuclear materials management. Prerequisite: Nuc Eng 3103 or Physics 2305.

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**NUC ENG 5365 Radiation Protection Engineering** (LEC 3.0)

Radiation fields and sources including nuclear reactors, radioactive wastes, x-ray machines, and accelerators. Stopping of radiation (Charges particles, photons, and neutrons) by matter. Radiation transport methods. Radiation shielding design. Dose rate calculations. Biological effects of radiation. Regulatory guides (10CFR20). Prerequisite: Nuc Eng 3205.

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**NUC ENG 5367 Radioactive Waste Management And Remediation** (LEC 3.0)

Sources and classes of radioactive waste, long-term decay, spent fuel storage, transport, disposal options, regulatory control, materials issues, site selection and geologic characterization, containment, design and monitoring requirements, domestic and foreign waste disposal programs, economic and environmental issues, history of disposal actions, and conduct of remedial actions and clean up. Prerequisite: Math 3304. (Co-listed with Geology 4421).

**NUC ENG 5370 Plasma Physics I** (LEC 3.0)

Single particle orbits in electric and magnetic fields, moments of Boltzmann equation and introduction to fluid theory. Diffusion of plasma in electric and magnetic fields. Analysis of laboratory plasmas and magnetic confinement devices. Introduction to plasma kinetic theory. Prerequisite: Aero Eng 3131 or Mech Eng 3131 or Physics 3211 or Nuc Eng 3221 or Elec Eng 3600. (Co-listed with Aero Eng 5570, Mech Eng 5570, Physics 4543).

**NUC ENG 5428 Reactor Laboratory I** (LEC 1.0 and LAB 1.0)

Acquaints the student with neutron flux measurement, reactor operation, control rod calibration, reactor power measurement and neutron activation experiments. Experiments with the thermal column and neutron beam port are also demonstrated. Prerequisites: Nuc Eng 4312, 3205.

**NUC ENG 5438 Reactor Laboratory II** (LEC 1.0 and LAB 1.0)

A continuation of Nuclear Engineering 304 with experiments of a more advanced nature. Prerequisite: Nuc Eng 4428.

**NUC ENG 5456 Reactor Operation II** (LAB 1.0)

The operation of the training reactor. The program is similar to that required for the NRC Reactor Operator's license. Students from other disciplines will also benefit from the course. Prerequisite: Nuc Eng 2105, 2406.

**NUC ENG 5507 Nuclear Policy** (LEC 3.0)

This course introduces nuclear security and safeguards policy. It explores the following topics: history of domestic and international nuclear policy, evolution of U.S. nuclear weapons policy, factors influencing policy, the IAEA, nuclear deterrence policy, nuclear safeguards policy, policy in non-proliferation issues, and various international agreements. Prerequisites: Graduate Standing or enrolled in the Nuclear Nonproliferation certificate program.

**NUC ENG 5509 Nuclear Nonproliferation** (LEC 3.0)

This course will introduce IAEA mission specific to nonproliferation. The class will provide discussion of essential elements of a nuclear weapon, followed by a brief historical over of nonproliferation treaties in place to deter proliferation. Methods of fissile material production will be discussed followed by a survey of tool and techniques available an Prerequisites: Graduate Standing or enrolled in the Nuclear Nonproliferation certificate program.

**NUC ENG 5577 Advanced Nuclear Forensics and Radiochemistry** (LEC 3.0)

Fundamentals of radiochemistry, including nuclear science, cosmochemistry, spent fuel reprocessing, with details on solvent extraction. We will review case studies in Nuclear Forensics. This advanced section also includes experiments on radiochemistry and demonstrate experimental nuclear forensics techniques. Dual listed with Nuc Eng 4577.

**NUC ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**NUC ENG 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**NUC ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**NUC ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**NUC ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**NUC ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

**NUC ENG 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**NUC ENG 6203 Advanced Reactor Physics** (LEC 3.0)

Transport and diffusion theory; multigroup approximation; criticality calculations; cross-section processing; buildup and depletion calculations; delayed neutrons and reactor kinetics; lattice physics calculations; full core calculations; analysis and measurement of reactivity coefficients. Prerequisite: Math 5325.

**NUC ENG 6205 Linear Transport Theory** (LEC 3.0)

Monoenergetic Boltzmann equation for neutral particles by the method of singular eigen-functions and polynomial expansions. Prerequisites: Nuc Eng 4203, Math 5358.

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**NUC ENG 6223 Nuclear Reactor Safety** (LEC 3.0)

Study of safety criteria; reactor characteristics pertinent to safety; reactor transient behavior; loss of coolant accident analysis; emergency core cooling; fuel behavior during accident conditions; reactor risk analysis; current reactor safety issues. Prerequisites: Nuc Eng 4203 and 3229.

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**NUC ENG 6241 Effects Of Radiation On Solids** (LEC 3.0)

The theories of the interaction of nuclear radiation with matter. Experimental approaches to radiation studies, including the sources and dosimetry. Nature and properties of crystal imperfections. The influence of radiation on physical, mechanical and surface properties of metals and alloys. Radiation effects on materials other than those incorporated in nuclear reactors. The annealing of defects. Prerequisite: Met Eng 5170.

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**NUC ENG 6257 Advanced Nuclear Thermal Hydraulics** (LEC 3.0)

Treatment of advanced topics in nuclear reactor thermal-hydraulics including analysis of fuel elements and fuel melting, multiphase flow dynamics and two-fluid models, interfacial transfer of mass, momentum, and energy, multiphase flow scaling, and numerical applications. Prerequisite: Math 5325.

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**NUC ENG 6325 Plasma Physics** (LEC 3.0)

Fundamentals of kinetic, theory, fluid equations, MHD equations, and applications: wave propagation, shielding effect, diffusion, stability, and charged particle trajectories. Prerequisite: Nuc Eng 4361 for Nuc Eng; Physics 4211 for Physics.

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**NUC ENG 6331 Radiation Shielding** (LEC 3.0)

Radiation sources; interactions of radiation with matter; dosimetry and radiation protection guidelines. The particle transport equation and methods of solving it; the Monte Carlo Method; special computational methods for neutron and gamma attenuation. Computer codes used in shielding. Shielding materials, shield design. Prerequisite: Nuc Eng 4203.

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## Petroleum Engineering (PET ENG)

**PET ENG 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects of projects in the department. Consent of instructor required.

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**PET ENG 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**PET ENG 5010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**PET ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**PET ENG 5085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**PET ENG 5099 Research** (IND 0.0-12)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**PET ENG 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects of projects in the department. Consent of instructor required.

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**PET ENG 6001 Special Topics** (LEC 2.0 and LAB 1.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**PET ENG 6010 Seminar** (IND 0.0-6.0)

Discussion of current topics.

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**PET ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**PET ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**PET ENG 6085 Internship** (IND 0.0-15)

Students working toward a doctor of engineering degree will select, with the advice of their committees, appropriate problems for preparation of a dissertation. The problem selected and internship plan must conform to the purpose of providing a high level engineering experience consistent with the intent of the doctor of engineering degree.

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**PET ENG 6099 Research** (IND 0.0-12)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

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**PET ENG 6211 Advanced Directional Drilling and MWD** (LEC 3.0)

In-depth study of directional well planning and drilling. The course covers the bottom hole assemblies and operational techniques used in directional drilling as well as the limiting factors and hole problems related to horizontal wells. Advanced research topics and well design in directional drilling. Prerequisites: Pet Eng 4210.

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**PET ENG 6231 Drilling Optimization** (LEC 3.0)

Optimization of the drilling process based on geomechanical model of the subsurface. Topics include drilling hydraulics, drilling bits, selection of operational parameters and analysis of drilling time and cost. Prerequisite: Pet Eng 4210.

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**PET ENG 6431 Advanced Well Completion Design** (LEC 3.0)

Overview of hardware, fluids and processes employed in completing oil and gas wells. Types of well completions and design considerations. Downhole mechanics, tubing movement and stress calculations. Advanced concepts in well completion design and review of well completions literature. Prerequisites: Pet Eng 4410.

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**PET ENG 6441 Advanced Well Stimulation** (LEC 3.0)

This course builds on the basic theory and fundamentals of hydraulic fracturing through the use of STIMPLAN software and hands on industry examples. The course teaches the methods used to plan, execute and evaluate hydraulic fracturing treatments. An advanced exercise and a research assignment are required. Students may not earn credit for both Pet Eng 4441 and Pet Eng 6441. Prerequisites: Pet Eng 3520 and Pet Eng 3310.

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**PET ENG 6521 Advanced Well Test Analysis** (LAB 1.0 and LEC 2.0)

Pressure transient analysis equations, well test analysis for fractured wells, horizontal wells, injection wells, and other special situations. Introduction to rate transient analysis. Prerequisites: Pet Eng 3520 and Pet Eng 4520.

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**PET ENG 6541 Advanced Reservoir Engineering I** (LEC 3.0)

Advanced study of producing mechanisms. Prerequisites: Pet Eng 5631 and Pet Eng 4520.

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**PET ENG 6551 Advanced Reservoir Engineering II** (LEC 3.0)

Flow through porous media: derivations and solutions for steady, semi-steady, and transient flow of single and multiple phase flow through porous media. Prerequisite: Pet Eng 3520.

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**PET ENG 6621 Advanced Applied Reservoir Simulation** (LEC 3.0)

Advanced simulation of actual reservoir problems using both field and individual well models to determine well spacing, production effects of secondary and enhanced recovery processes, future rate predictions and recovery, coning effects, relative permeability adjustments and other history matching techniques. Prerequisite: Pet Eng 4621 or equivalent.

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**PET ENG 6631 A Survey Of Improved Recovery Processes** (LEC 3.0)

An overview of current advanced recovery methods including secondary and tertiary processes. An explanation of the primary energy mechanism and requirements of these methods and an analysis of laboratory results and their subsequent field applications. Prerequisite: Pet Eng 4611.

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**PET ENG 6711 Geodynamics** (LEC 3.0)

The applications of continuum physics to geological and petroleum engineering problems. Topics include plate tectonics, stress and strain in solids, elasticity and flexure, heat transfer, gravity, fluid mechanics, rock rheology, faulting, and flow in porous media. Prerequisites: Math 2222 and Geology 3310. (Co-listed with Geology 6211).

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**PET ENG 6811 Advanced Offshore Petroleum Technology** (LEC 3.0)

A study of factors affecting offshore structural design and operation. Focus is on mobile offshore drilling units (MODUs). Subsea well systems and offshore pipelines are covered. Advanced topics in system design. Prerequisites: Pet Eng 4210, Civ Eng 3330, Civ Eng 2210.

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## Physics (PHYSICS)

**PHYSICS 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**PHYSICS 5001 Special Topics** (IND 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**PHYSICS 5333 Subatomic Physics** (LEC 3.0)

An introduction to elementary particles. Topics include particle properties, nuclear forces, particle interactions, the Standard Model for quarks and leptons, fundamental forces in gauge field theory models, and the role of elementary particle interactions in cosmology. Prerequisite: Physics 3311.

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**PHYSICS 5403 Computational Physics** (LEC 3.0 and LAB 1.0)

An introduction to modern computer simulations for solving physics problems. The course will be project-oriented with examples including planetary motion, chaotic dynamics, quantum scattering, structure of atoms and clusters, molecular dynamics, and Monte-Carlo simulations. Prerequisites: Physics 2305 or Physics 2311; Math 3304; programming experience.

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**PHYSICS 5413 Chaos, Fractals, and Nonlinear Dynamics** (LEC 3.0)

An introduction into nonlinear dynamics, deterministic chaos, and fractals. Topics covered include phase plane analysis, iterated maps, routes to chaos, Lyapunov exponents, strange attractors and pattern formation with applications to chaotic vibrations, population dynamics, chemical oscillations and lasers. Prerequisites: Math 3304; Physics 2135 or Physics 2111.

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**PHYSICS 5503 Fourier Optics** (LEC 3.0)

Applications of Fourier analysis and linear system theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both Elec Eng 3430 and Elec Eng 3600 or Physics 4211. (Co-listed with ELEC ENG 5210).

**PHYSICS 5513 Fiber And Integrated Optics** (LEC 3.0)

Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: Elec Eng 3600 or Physics 4211. (Co-listed with Elec Eng 5220).

**PHYSICS 5603 Advanced Physics Laboratory Teaching Methods** (LEC 3.0)

Objectives, methods and problems related to teaching of introductory physics, with an emphasis on laboratory instruction, the development of educational laboratory experiments and techniques, student learning styles, student assessment, student work groups, computer-based data acquisition, and communication techniques. Prerequisite: Graduate standing.

**PHYSICS 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PHYSICS 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**PHYSICS 6002 Coop Registration** (IND 0.0-1.0)

Doctoral candidates participating in a cooperative program with another UM campus must enroll for one hour of credit for their first semester in the program and zero hours of credit for successive registration periods until degree is completed. Failure to do so may invalidate candidacy. Billing is automatic as is registration upon payment.

**PHYSICS 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**PHYSICS 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**PHYSICS 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**PHYSICS 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**PHYSICS 6101 Classical Mechanics I** (LEC 3.0)

Methods of Newton, Lagrange, and Hamilton applied to the motion of particles and rigid bodies. Introduction to canonical transformations and Poisson brackets. Classical scattering and small oscillations. Prerequisites: Math 3304 and Physics 3201.

**PHYSICS 6111 Electrodynamics I** (LEC 3.0)

A rigorous development of the fundamentals of electromagnetic fields and waves. Electrostatics, magnetostatics, Maxwell's equations—Green's function, boundary value problems, multipoles, conservation laws. Prerequisites: Physics 4211.

**PHYSICS 6201 Quantum Mechanics I** (LEC 3.0)

Basic formalism applied to selected problems. Schroedinger equation and one dimensional problems, Dirac notation, matrix mechanics, harmonic oscillator, angular momentum, hydrogen atom, variational methods, introduction to spin. Prerequisite: Physics 4301 or equivalent.

**PHYSICS 6211 Electrodynamics II** (LEC 3.0)

A continuation of Physics 5211+D1067. Applications of time-dependent Maxwell's equations to such topics as plasmas, wave guides, cavities, radiation; fields of simple systems and multipoles. Relativity; covariant formulation of Maxwell's equations and conservation laws, fields of uniformly moving and accelerated charges. Prerequisite: Physics 5211.

**PHYSICS 6301 Quantum Mechanics II** (LEC 3.0)

Perturbation theory, treatment of spin, angular momentum addition, Wigner-Eckart theorem; scattering theory including partial wave analysis, born approximation, and formal scattering theory; identical particles, introduction to second quantization, and structure of complex atoms. Prerequisite: Physics 5301.

**PHYSICS 6311 Statistical Mechanics** (LEC 3.0)

A study of statistical ensembles; Maxwell-Boltzmann, FermiDirac and Einstein-Bose distribution laws, application to some simple physical systems. Prerequisites: Physics 4311, Physics 5301.

**PHYSICS 6323 Quantum Statistical Mechanics** (LEC 3.0)

Techniques for calculation of the partition function with examples drawn from interacting Fermi gas, interacting Bose gas, superconductors, and similar sources. Prerequisites: Physics 6311 and 6301.

**PHYSICS 6333 Condensed Matter Physics** (LEC 3.0)

A course in the physics of hard and soft matter including solids, liquids, and complex materials. Topics: atomic structure, mechanical properties, phonons, electronic structure, energy band theory, electronic correlations, transport properties, magnetism, superconductivity. Prerequisite: Physics 5301.

**PHYSICS 6353 Atomic And Molecular Structure** (LEC 3.0)

Applications of quantum mechanics to the structure of atoms and molecules; perturbation and variational calculations, self-consistent field, multiplets, angular momenta, Thomas-Fermi model, diatomic molecules, spectral intensities. Prerequisite: Physics 5301.

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**PHYSICS 6363 Atomic Collisions** (LEC 3.0)

Basic quantum mechanical concepts involved in atomic scattering theory. Topics include the Born approximation elastic collisions, and inelastic collisions. Other specific topics will be chosen from the general areas of electron, ion, and atom collisions with atoms and molecules. Prerequisite: Physics 6353 or 6301.

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**PHYSICS 6403 Mathematical Physics I** (LEC 3.0)

Vector spaces, generalized coordinate transformations, vector analysis, tensors, partial differential equations in physics and boundary value problems, orthogonal functions and solutions to ordinary differential equations, hypergeometric, confluent hypergeometric, Legendre, Laguerre, and Bessel functions, Hermite polynomials, Green's functions in one dimension. (Co-listed with Math 6802).

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**PHYSICS 6413 Mathematical Physics II** (LEC 3.0)

Green's functions in three dimensions, integral equations, complex variable theory and contour integration, group theory with applications to quantum mechanics, solid state and molecular physics. Prerequisite: Math 6802 or Physics 6403. (Co-listed with Math 6803).

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## Psychology (PSYCH)

**PSYCH 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**PSYCH 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new graduate level course. Variable title.

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**PSYCH 5010 Seminar for Industrial / Organizational Psychology** (RSD 3.0)

A seminar course for general overviews of the most recent research in Industrial-Organizational Psychology. Prerequisite: Graduate standing.

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**PSYCH 5012 Ethics and Professional Responsibilities** (LEC 1.0)

Case studies examining the ethical practice of psychology in organizations will be discussed. This will include covering both the legal and ethical standards surrounding the consulting and practice of I-O psychology and personnel management in organizations. Prerequisite: Graduate standing.

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**PSYCH 5020 Introduction to Industrial-Organizational Psychology** (LEC 3.0)

Review of the most recent theoretical and applied research in advanced personnel and organizational psychology. Topics will include personnel selection, training and performance appraisal, job attitudes, motivation, work groups and teams, leadership, organizational culture, and organizational development. Prerequisites: Graduate Standing.

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**PSYCH 5040 Oral Examination** (IND 0.0)

(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./PH.D students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**PSYCH 5200 Theories and Practice of Psychological Measurement** (LEC 3.0)

An overview of psychological tests and batteries used in a variety of disciplines. An emphasis is placed on the proper development and use of these tests and test batteries. Tests examined will include tests of intelligence, aptitude, personality, and psychopathology. Prerequisite: Psych 4200 or graduate standing.

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**PSYCH 5201 Psychometrics** (LEC 3.0)

An examination of statistical methods used to develop and refine measures of human performance, aptitudes, and personality. Topics include reliability and validity, data reduction, measuring inter-relationships among variables (e.g., factor analysis, multiple regression), and testing group differences. Prerequisite: Psych 5202.

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**PSYCH 5202 Applied Psychological Data Analysis** (LEC 3.0)

This course will focus on those statistical methods most useful for advanced research in psychology. We will learn to use R, a powerful, open-source statistical programming platform, and work through examples with psychological data sets including such techniques as correlation, ANOVAs, regression, and chi-squared. Prerequisite: Graduate standing.

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**PSYCH 5210 Advanced Research Methods** (LEC 3.0)

Research methods and techniques, with an emphasis on conducting psychological research in organizational settings. Topics discussed include: ethics, reliability and validity in measurement and application, proper uses of experimental, quasi-experimental, and survey methodologies, as well as advanced methodologies IRT, SEM, HLM, and Meta-Analyses. Prerequisite: Graduate standing.

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**PSYCH 5600 Advanced Social Psychology** (LEC 3.0)

An advanced study of the behavior of individuals in interaction within groups. Consideration will also be given to the experimental literature dealing with the formal properties of groups, conformity and deviation, intergroup relations, and attitude formation and attitude change. Prerequisite: Psych 4600 or graduate standing.

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**PSYCH 5601 Small Group Dynamics** (LEC 3.0)

This course covers group perception, identification, leadership, structure, conflict, cohesion, commitment, performance, norms, roles, influence, and decisions, and groups' relations, networks, and work teams. Students consider both theory and applications to their lives and organizations through observational, research, team and applied assignments. Prerequisite: Psych 4601 or graduate standing.

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**PSYCH 5602 Organizational Development** (LEC 3.0)

Examination of the field of organizational development theories and interventions. An emphasis is placed on research methods and application of practices related to individual processes, group processes, and organizational structures and functions that impact change and development strategies and interventions. Prerequisite: Psych 4602 or graduate standing.

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**PSYCH 5603 Advanced Social Influence** (LEC 3.0)

An in-depth review of the principles and procedures that affect the process of social influence, with consideration given to attitudinal, compliance inducing, and perceptual influences. Students will consider the theoretical implications and practical applications of topics in social influence in the form of independent reading, research proposals and/or projects, and observational assignments. Prerequisite: Psych 4603 or graduate standing.

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**PSYCH 5700 Job Analysis and Performance Management** (LEC 3.0)

A focus on the scientific measurement of job performance. An in-depth discussion of the science and methods of appropriate job and task analysis will be discussed. Additionally, students will focus on current issues in performance management and appraisal including scientific findings related to both objective and subjective measures of performance. Prerequisite: Psych 4700 or graduate standing.

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**PSYCH 5710 Advanced Human Factors** (LEC 3.0)

An in-depth review of the foundations of human factors, focusing on the interaction of people with various forms of technology in a variety of environments. Topics include research and evaluation methods, displays (e.g., visual, auditory), attention and information processing, decision making, motor skills, anthropometry, and biomechanics. (Co-listed with ENG MGT 5330).

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**PSYCH 5720 Advanced Human-Computer Interaction** (LEC 3.0)

This course examines the psychological research and theories that contribute to the field of human-computer interaction. An emphasis will be placed on engaging in critical evaluation of research and applying theoretical knowledge to effectively use computers in organizations. Prerequisite: Psych 4720 or graduate standing.

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**PSYCH 5730 Environmental Psychology: Research and Practice** (LEC 3.0)

An in-depth review of the theoretical perspectives in environmental psychology and the psychological effects of various environments. An emphasis is placed on the review and integration of the research to explain the psychological issues related to various environments as well as to understand ways to effectively design living, educational, work, and recreational environments. Prerequisite: Psych 4730 or graduate standing.

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**PSYCH 6085 Internship** (IND 0.0-6.0)

Students will apply critical thinking skills and discipline specific knowledge in a work setting based on a project designed by the advisor and employee. Activities will vary depending on the student's background and the setting. Requires a major report. Prerequisites: Completed Core and Methods courses; instructor consent.

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**PSYCH 6099 Research** (IND 0.0-6.0)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisites: Consent of instructor required.

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**PSYCH 6602 Employee Affect and Behavior** (LEC 3.0)

Theory and research surrounding employee attitudes, emotions, and behaviors with an emphasis on antecedents and outcomes of: job satisfaction, engagement, organizational justice, trait and state positive and negative affect, organizational citizenship, counterproductive work, and proactive behaviors and the Implications for both employees and organizations. Prerequisite: Psych 5020.

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**PSYCH 6610 Leadership, Motivation, and Culture** (LEC 3.0)

Examination of research related to leadership, motivation, and the impact of organizational culture on organizational performance will be discussed. The course will focus on the application of psychological theories to enhance organizational functioning and to promote positive workplace behaviors. Prerequisite: Psych 5020.

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**PSYCH 6611 Leadership for Engineers** (LEC 3.0)

Provides engineers with a background in leadership concepts and principles; enables students to develop practical skills in leading and managing through multiple personal assessment. Topics include leadership styles, managing commitments, conflict resolution, change management, emotional intelligence, team dynamics and business ethics. Prerequisite: Eng Mgt 5110 or Psych 4602.

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**PSYCH 6700 Training and Development** (LEC 3.0)

Psychological theories of learning will be covered. Students will learn how evaluate training needs in an organization as well as how to subsequently develop, implement, and validate a training program in an organizational context. Prerequisite: Psych 5700.

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**PSYCH 6702 Personnel Selection** (LEC 3.0)

Current trends and methods in personnel recruitment and selection including classification, and promotion will be examined. An emphasis will be placed on legal and methodological considerations that can impact proper testing and assessment procedures. Cognitive abilities, personality, physical abilities, and other non-cognitive assessments will be discussed. Prerequisite: Psych 5700.

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## Statistics (STAT)

**STAT 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**STAT 5001 Special Topics** (IND 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**STAT 5099 Graduate Research** (IND 0.0-6.0)

Investigation of an advanced nature leading to the preparation of a MS thesis or dissertation.

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**STAT 5260 Statistical Data Analysis Using SAS** (LEC 2.0 and LAB 1.0)

This course will introduce the student to selected data analytic tools implemented in the Statistical Analysis System (SAS) and appropriate and effective use of these tools. Focus would be on both the use of SAS data analytic tools and the theoretical and methodological rationale that form the basis of such analyses. Prerequisite: One of Stat 3113 or 3115 or 3117 or 5643; and one of Stat 5346 or 5353 or 6841 or 6343 or 6344 or 6545.

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**STAT 5346 Regression Analysis** (LEC 3.0)

Simple linear regression, multiple regression, regression diagnostics, multicollinearity, measures of influence and leverage, model selection techniques, polynomial models, regression with autocorrelated errors, introduction to non-linear regression. Prerequisites: Math 2222 and one of Stat 3111, 3113, 3115, 3117, or 5643. (Co-listed with Comp Sci 5204).

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**STAT 5353 Statistical Data Analysis** (LEC 3.0)

Introduction to methods for analyzing statistical data from experiments and Introduction to methods for analyzing statistical data from experiments and surveys. Analysis of variance, correlation, introduction to regression techniques, contingency tables, non-parametric techniques and introduction to modern statistical software. Prerequisites: Math 2222 and one of Stat 1115, 3113, 3115 and 3117.

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**STAT 5425H Introduction to Biostatistics-Honors** (LAB 1.0 and LEC 3.0)**STAT 5643 Probability And Statistics** (LEC 3.0)

Introduction to the theory of probability and its applications, sample spaces, random variables, binomial, Poisson, normal distributions, derived distributions, and moment generating functions. Prerequisite: Math 2222.

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**STAT 5644 Mathematical Statistics** (LEC 3.0)

A continuation of Stat 5643 with introduction to the theories of point estimation, hypothesis testing, and interval estimation. Includes sufficiency, completeness, likelihood and how they apply to the exponential family. Prerequisite: Stat 5643.

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**STAT 5755 Statistical Models in Actuarial Science** (LEC 3.0)

This course covers the statistical foundation of actuarial models and their applications. Topics include survival and severity models, Kaplan-Meier and Nelson-Aalen estimators, aggregate and credibility models for insurance losses, discrete time Markov chains, ruin theory, and simulation. Prerequisite: Stat 5643 and either Stat 5644 or a 3000-level Stat course. (Co-listed with Econ 4350).

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**STAT 5756 Statistical Models for Life Contingencies** (LEC 3.0)

The basic statistical theory of actuarial models for life uncertainties such as time of death. Multiple life and multiple decrement models, statistical models for life and contingent insurance; last survivor, disability, withdrawal, retirement and reserving models for life insurance. Prerequisite: Stat 5643.

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**STAT 5756H Stat Models for Life Cont-Honors** (LEC 3.0)**STAT 5814 Applied Time Series Analysis** (LEC 3.0)

Introduction to time series modeling of empirical data observed over time. Topics include stationary processes, autocovariance functions, moving average, autoregressive, ARIMA, and GARCH models, spectral analysis, confidence intervals, forecasting, and forecast error. Prerequisites: One of Stat 3113, 3115, 3117, 5643 and one of Math 3103, 3108, or 5108.

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**STAT 5904 Science Education and Quantitative Literacy for Middle School Teachers** (LEC 3.0)

An integrated science-mathematics course for middle school teachers. Course covers selected science/mathematics topics/skills specified in Missouri standards for grades 5-7. Inquiry based methods of teaching these topics in an integrated manner will be emphasized. Prerequisite: Current enrollment in a Teacher Education Program or a full or part-time teacher in a K-12 school. (Co-listed with Physics 4625).

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**STAT 5905 Making Sense Of Data For Elementary School Teachers** (LEC 3.0)

An activity based course that is intended to provide elementary school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint. Prerequisite: Graduate Standing.

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**STAT 5906 Making Sense Of Data For Middle School Teachers** (LEC 3.0)

An activity based course that is intended to provide middle school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

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**STAT 5907 Making Sense Of Data For High School Teachers** (LEC 3.0)

An activity based course that is intended to provide high school teachers with the skills necessary to implement the Probability & Statistics strand of the American Statistical Association of the National Council of Teachers of Mathematics (NCTM) joint.

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**STAT 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects in the department. Consent of instructor required.

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**STAT 6001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**STAT 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**STAT 6050 Continuous Registration** (LEC 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

**STAT 6099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**STAT 6238 Stochastic Optimization** (LEC 3.0)

Introduction to stochastic modeling theory and application. Topics include probability theory, Markov processes, renewal theory, and queuing theory. Additional topics include stochastic dynamic programming and stochastic programming. Prerequisite: Eng Mgt 5412. (Co-listed with Eng Mgt 6414).

**STAT 6239 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Sys Eng 6214 and Comp Sci 6405).

**STAT 6342 Categorical Data Analysis** (LEC 3.0)

A graduate-level introduction to statistical methods for analyzing categorical data. The topics include: contingency tables, generalized linear models including logistic regression models, log-linear models, ordinal and nominal regression models, Poisson regression, etc. The course will involve practical applications of the ideas and their implementations. Prerequisites: Stat 5644 and one of Stat 5346, Stat 5353, Stat 6344, or Stat 6553.

**STAT 6343 Nonparametric Statistical Methods** (LEC 3.0)

A course covering distribution free statistical methods. Topics include: order statistics, tests of hypotheses for one-sample and two-sample problems, analyses of variance, goodness-of-fit tests, runs test, independence and regression problems, point and interval estimation, ARE. Prerequisite: Stat 5644.

**STAT 6344 Design And Analysis Of Experiments** (LEC 3.0)

Experimental designs and their statistical analysis. Includes completely randomized designs, complete and incomplete blocking designs, factorial and fractional factorial experiments, multiple comparisons, response surface analysis. Prerequisites: One of Stat 5353, Eng Mgt 5715 and one of Stat 3111, 3113, 3115, 3117, 5643; or Stat 5643 and one of Stat 3111, 3113, 3115, 3117.

**STAT 6545 Multivariate Statistical Methods** (LEC 3.0)

Analysis of data consisting of simultaneous measurements on many variables. Multivariate normal distribution, multivariate analysis of variance, canonical correlation, principal components, classification and clustering techniques. Prerequisites: Stat 5644 and Math 3103.

**STAT 6553 Linear Statistical Models I** (LEC 3.0)

Includes a development of the theory of the distribution of quadratic forms, and the estimation of parameters and testing hypotheses in linear statistical models. Prerequisites: Math 3108 and Stat 5643 and either Stat 5353 or 5644.

**STAT 6554 Linear Statistical Models II** (LEC 3.0)

Includes the theory of polynomial models, regression models, experimental design models, incomplete block models, nonlinear models, with emphasis on optimum properties of point and interval estimation and the power of tests. Prerequisite: Stat 6553.

**STAT 6570 Theory Of Reliability** (LEC 3.0)

Statistical analyses of life-testing distributions such as the Weibull, gamma, exponential, logistic, and normal. Reliability estimation, tolerance limits, censored sampling, and applications of Monte-Carlo simulation. Prerequisite: Stat 5644.

**STAT 6657 Advanced Mathematical Statistics I** (LEC 3.0)

The theory of estimation and hypothesis testing. Completeness and sufficiency. Maximum likelihood, minimax, Bayesian and invariant procedures for testing. Sequential decision rules. Emphasis on estimation. Prerequisites: Stat 5644 and Math 5215.

**STAT 6658 Advanced Mathematical Statistics II** (LEC 3.0)

A continuation of Stat 6657 with the emphasis on hypothesis testing. Prerequisite: Stat 6657.

**STAT 6814 Statistical Time Series Analysis** (LEC 3.0)

A formal introduction to the fundamentals of statistical modeling and analysis of discrete time series. Topics include autoregressive and moving average processes, ARMA models, second order stationarity, vector processes, autocorrelation function, Fourier representation, estimation and prediction of time series. Prerequisites: Stat 5643 and Math 3103 or 3108.

**STAT 6841 Stochastic Processes** (LEC 3.0)

Development and application of Poisson and nonhomogeneous Poisson processes; renewal processes; Markov chains and processes including birth and death processes; and normal processes, including Brownian motion. Prerequisites: Stat 5643 and Math 3304 or 3329.

**STAT 6846 Advanced Probability Theory** (LEC 3.0)

Probability spaces, random variables, distribution functions, expectations, independence, convergence theorems, characteristic functions, moment generating functions, and central limit theorem. Prerequisites: Stat 5644 and Math 5215.

## Systems Engineering (SYS ENG)

**SYS ENG 5000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**SYS ENG 5001 Special Topics** (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**SYS ENG 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**SYS ENG 5099 Research** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

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**SYS ENG 5101 System Engineering and Analysis** (LEC 3.0)

The concepts of Systems Engineering are introduced through a project. Students work in virtual teams. The topics covered are architecture development, basic system architectural design techniques, functional decomposition, design and technical review objectives, and initial specifications. Prerequisite: Graduate Standing.

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**SYS ENG 5105 Project Management** (LEC 3.0)

Organization structure and staffing; motivation, authority and influence; conflict management; project planning; network systems; pricing, estimating, and cost control; proposal preparation; project information systems; international project management. Prerequisites: Graduate standing. (Co-listed with Eng Mgt 5320).

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**SYS ENG 5211 Computational Intelligence** (LEC 3.0)

Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Elec Eng 5810 and Comp Eng 5310).

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**SYS ENG 5212 Introduction to Neural Networks and Applications** (LEC 3.0)

The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Elec Eng 5370).

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**SYS ENG 5323 Wireless Networks** (LAB 1.0 and LEC 2.0)

Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Comp Eng 5430 and Elec Eng 5430).

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**SYS ENG 6000 Special Problems** (IND 1.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

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**SYS ENG 6001 Special Topics** (LEC 1.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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**SYS ENG 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

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**SYS ENG 6040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examination for on-campus MS/PhD students may be processed during intersession. Off-campus MS students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive exam (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

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**SYS ENG 6050 Continuous Registration** (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from campus must continue to enroll for at least one credit hour each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

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**SYS ENG 6099 Research** (IND 1.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required. Prerequisite: Graduate standing.

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**SYS ENG 6101 Advanced Research Methodology in Engineering Management** (LEC 3.0)

An advanced study of research methodology techniques and theories in conducting research activities. The research problems, hypotheses, literature search, data requirements and analyses, interpretation and presentation of results are examined. Prerequisite: Graduate standing. (Co-list with Eng Mgt 6101).

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**SYS ENG 6102 Information Based Design** (LEC 3.0)

This course is an introduction to the use of common data analytical methods and analysis for the purpose of decision making during the design phase of engineering system development. Through the introduction to such analytical methodologies, the systems engineering tool belt is made more effective as it is the foundation to decision analysis. Prerequisites: Graduate Standing.

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**SYS ENG 6103 Systems Life Cycle Costing** (LEC 3.0)

Methods of economic evaluation for engineering projects involving complex systems. Economic impacts on choosing system alternatives, life cycle costing, economic decisions involving risk and uncertainty, and engineering cost estimation for projects in government, defense, and commercial industries. Prerequisites: Graduate Standing.

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**SYS ENG 6104 Systems Architecting** (LEC 3.0)

Tools and concepts of architecting complex engineering systems. Ambiguity in Systems Architecting and Fuzzy Systems; Search as an Architecting Process; Architecting Heuristics; Systems Scoping and Attribute Selection; Assessing Architectures; Systems Aggregation, Partitioning; Systems Behavior Generation; System Science and Thinking, Cyber Physical Systems. Prerequisites: Graduate Standing.

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**SYS ENG 6105 Complex Engineering Systems Project Management** (LEC 3.0)

The course topics include issues specific to distributed project management, team development, resource management, constraint planning, development of Integrated Master Schedule and Integrated Master Plan, monitoring technical performance, schedule, cost, and risk. Prerequisites: Graduate Standing.

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**SYS ENG 6110 Optimization under Uncertainty** (LEC 3.0)

Optimization in the presence of model uncertainty or system stochasticity is discussed. The course covers fundamentals of stochastic programming, robust optimization, and dynamic programming. Prerequisite: Graduate standing. (Co-listed with ENG MGT 6415).

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**SYS ENG 6167 Software Intensive Systems Architecting** (LEC 3.0)

Basic tools and concepts of architecting complex software intensive systems are introduced. The following topics are covered under four main sections; namely Architecting Process, Architecting Heuristics, Architecting Patterns and Frameworks, and Architecture Assessment. Prerequisite: Graduate Standing.

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**SYS ENG 6196 Systems Engineering Capstone** (LEC 3.0)

The topics covered are Systems Engineering Management Plan (SEMP), Systems Engineering processes, process re-engineering, standards, and systems engineering case studies. Students will apply the skills and theory that they mastered in previous five core courses to the analysis of assigned cases. Prerequisites: Sys Eng 6105.

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**SYS ENG 6213 Deep Learning and Advanced Neural Networks** (LEC 3.0)

Use of deep learning and advanced neural networks in the design of cyber physical complex adaptive systems. Machine learning basics, deep feed forward networks, regularization for deep learning, optimization for training deep models, convolutional networks, recurrent and recursive nets, practical, vision and natural language processing applications. Prerequisite: Graduate Standing.

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**SYS ENG 6214 Clustering Algorithms** (LEC 3.0)

An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student's degree program. (Co-listed with Comp Eng 6330, Elec Eng 6830, Comp Sci 6405 and Stat 6239).

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**SYS ENG 6215 Adaptive Dynamic Programming** (LEC 3.0)

Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Elec Eng 6360, Mech Eng 6458 and Aero Eng 6458).

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**SYS ENG 6216 Advanced Topics in Data Mining** (LEC 3.0)

Advanced topics of current interest in the field of data mining. This course involves reading seminal and state-of-the-art papers as well as conducting topical research projects including design, implementation, experimentation, analysis, and written and oral reporting components. Prerequisite: A "C" or better grade in Comp Sci 5001 Introduction to Data Mining. (Co-listed with Comp Sci 6402 and Comp Eng 6302).

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**SYS ENG 6217 Markov Decision Processes** (LEC 3.0)

Introduction to Markov Decision Processes and Dynamic Programming. Application to Inventory Control and other optimization and control topics. Prerequisites: Graduate standing in background of probability or statistics. (Co-listed with Comp Eng 6310, Mech Eng 6447, Aero Eng 6447, Eng Mgt 6410, and Comp Sci 6202).

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**SYS ENG 6239 Smart Engineering System Design** (LEC 3.0)

Covers the tools, techniques and methods used in developing Flexible Intelligent Learning Architectures for system of systems (SoS) and cyber physical systems (CPS) through evolutionary approach. Meta-architecture generation algorithms, SoS and CPS architecture evaluation methods, executable architectures, many meta-architecture objectives trade. Prerequisites: Graduate Standing.

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**SYS ENG 6321 Modeling Complex Systems** (LEC 3.0)

Engineering Systems of today are non-linear, distributed, global, and adaptive to their environment in both space and time, thereby creating emergent behaviors. This course covers the current modeling tools and techniques used in modeling and architecting these complex systems. Prerequisites: Graduate Standing. (Co-listed with COMP ENG 6410).

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**SYS ENG 6322 Resilient Networks** (LEC 3.0)

This course presents reliability and fault tolerance for network-centric systems, including models, metrics, and analysis techniques. This course also concentrates on security, including technical tools and methods for audit and assessment as well as management and policy issues. Prerequisites: Sys Eng 6410, Comp Eng 6410, or Comp Eng 5420. (Co-listed with COMP ENG 6510).

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**SYS ENG 6324 Wireless Ad hoc and Sensor Networks** (LEC 3.0)

Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Elec Eng 6430).

**SYS ENG 6412 Mathematical Programming** (LEC 3.0)

Linear optimization and its engineering applications; problem modeling, search-based optimization, the simplex method for solving linear problems, multi-objective optimization, discrete dynamic programming. Applications of optimization in the fields such as transportation, project management, manufacturing and facility location will be discussed. Prerequisites: One of the following: Stat 3113, Stat 3115, or Stat 3117; Math 3108. (Co-listed with Math 6665 and Eng Mgt 6412).

**SYS ENG 6541 Distributed Systems Modeling** (LEC 3.0)

This course will discuss issues related to distributed systems architecting, modeling, analysis and representation, with specific focus on discrete-part manufacturing domain. Distributed modeling techniques and other model decomposition methods using simulation modeling and scalability issues will also be addressed.

**SYS ENG 6542 Model Based Systems Engineering** (LEC 3.0)

Provides the student with understanding of the use of models to represent systems and validate system architectures. The student will gain proficiency in using a systems modeling language and shifting systems engineering from a document centric to a model centric paradigm. Prerequisites: Graduate Standing. (Co-listed with COMP SCI 6102).

**SYS ENG 6612 Investment** (LEC 3.0)

An introduction to the theory and practice of investment, including financial markets and instruments, security trading, mutual funds, investment banking, interest rates, risk premiums, the capital asset pricing model, arbitrage pricing theory, market efficiency, bonds and the fixed income market, equity valuation, fundamental and technical analysis. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6212).

**SYS ENG 6613 Financial Engineering** (LEC 3.0)

An introduction to financial engineering, with an emphasis on financial derivatives, including the future markets, the pricing of forwards and futures, forward rate agreements, interest and exchange rate futures, swaps, the options markets, option strategies, the binomial and Black-Scholes models for option valuation, the option Greeks, and volatility smiles. Prerequisites: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6213).

**SYS ENG 6614 Financial Engineering II** (LEC 3.0)

This course introduces advanced topics in financial engineering, which includes introduction to Wiener processes, martingales and Ito's lemma; basic numerical methods for options pricing, exotic options; interest rate models; stochastic volatility models and jump-diffusion models; and value-at-risk. Prerequisite: Eng Mgt 6213/Sys Eng 6613. (Co-listed with Eng Mgt 6214).

**SYS ENG 6615 Financial Risk Management** (LEC 3.0)

Techniques and methods for managing financial risk, including portfolio theory, Monte Carlo methods, ARIMA, time series forecasting, Value-at-Risk, stress testing, extreme value theory, GARCH and volatility estimation, random variables and probability distributions, real options, decision trees, utility theory, statistical decision techniques, and game theory. Prerequisite: Eng Mgt 1210 or 5210. (Co-listed with Eng Mgt 6215).

## Technical Communication (TCH COM)

**TCH COM 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**TCH COM 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**TCH COM 5010 Seminar** (RSD 0.0-6.0)

Discussion of current topics. Prerequisites: One semester of college composition or technical writing, or graduate standing.

**TCH COM 5040 Oral Examination** (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**TCH COM 5099 Research** (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

**TCH COM 5510 Technical Editing** (LEC 3.0)

The principles and practices of technical editing, including usability, audience analysis, contextual editing, the conventions of scientific and technical communication, and the role of the editor in document development and publication. Students will also learn standard practices of copy editing and the use of style guides. Prerequisites: One semester of college composition or technical writing, or graduate standing.

**TCH COM 5520 Help Authoring** (LEC 3.0)

Students will acquire the technological and rhetorical skills necessary for creating effective online help systems, including context-sensitive help for computer applications. Prerequisites: One semester of college composition or technical writing, or graduate standing.



***TCH COM 5530 Usability Studies*** (LEC 3.0)

Students in this course will study and apply methods used by technical communicators to evaluate usability. Students will study methods used to evaluate human interaction with communication tools and how to make those products more suitable for human use. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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***TCH COM 5540 Advanced Layout and Design*** (LEC 3.0)

Advanced theory and practice of layout and design for print and electronic media. Prerequisite: English 2540 or TCH COM 2540, or graduate standing.

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***TCH COM 5550 Advanced Proposal Writing*** (LEC 3.0)

Familiarizes graduate students with many aspects of writing proposals for various purposes in academic, professional, and public spheres. Offers opportunities to write documents to promote their academic, professional, or personal goals or those of their organization(s). Credit will not be given for both TCH COM 4550 and TCH COM 5550. Prerequisites: Graduate standing.

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***TCH COM 5560 Web-Based Communication*** (LEC 3.0)

Covers such topics as advanced writing and editing for the web; the creation of rhetorically effective websites; the use of blogs, wikis, and other web genres to communicate technical information. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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***TCH COM 5610 History of Technical Communication*** (LEC 3.0)

Introduction to the roles of the technical communicator and the technologies of communication from ancient cultures to the present. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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***TCH COM 5620 Research Methods in Technical Communication*** (LEC 3.0)

Students learn essential research methods in technical communication, including audience analysis, interviewing techniques, working with subject matter experts, and experimental research design. Prerequisites: One semester of college composition or technical writing, or graduate standing.

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***TCH COM 6001 Special Topics*** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

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***TCH COM 6070 Teaching of Technical Communication*** (LEC 3.0)

Provides a theoretical and pedagogical foundation for teaching workshops and undergraduate courses in technical communication. Includes both traditional and electronic settings.

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***TCH COM 6410 Theoretical Approaches to Technical Communication*** (LEC 3.0)

Examines representative theories and research in written, oral, and visual modes of technical communication. Includes such issues as ethics, document design, rhetorical methods, and people-machine communication.

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***TCH COM 6420 Project Management in Technical Communication*** (LEC 3.0)

Study of and practice in directing projects related to such areas as multimedia, web sites, strategic planning, newsletters. Includes writing planning documents, selecting team members, synchronizing assignments, testing prototypes, and issuing a final report.

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***TCH COM 6440 Advanced Theories of Visual Technical Communication*** (LEC 3.0)

An in-depth investigation and analysis of historical and contemporary visual theories and their impact on technical communication, including visual rhetoric, semiotics, and design and critical theories.

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***TCH COM 6450 Advanced International Technical Communication*** (LEC 3.0)

Advanced study of international technical communication. Includes topics such as graphics, icons, symbols; user interface design; intercultural communication. Students may not earn credit for both TCH COM 4450 and TCH COM 6450.

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***TCH COM 6600 Foundations of Technical Communication*** (LEC 3.0)

Introduction to themes and issues, methods, and genres that define technical communication.

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# NON-DEGREE GRADUATE COURSE LIST

The following disciplines (aerospace studies, architectural engineering, art, economics, education, English, enterprise resource planning, finance, French, German, history, marketing, music, philosophy, political science, pre-med, psychology, Russian, Spanish, speech and media studies, and theatre) do not offer a graduate degree. The departments of economics and finance, English and history & political science have entered into cooperative agreements with the corresponding departments of the University of Missouri-St. Louis to offer a master of arts in economics and in English. The agreements permit students to take a maximum of 12 semester hours on the Missouri S&T campus. Some of the upper division courses may be used, where pertinent, for credit toward other graduate degrees. Be sure to check the use of these courses with your major professor before you add these courses to your schedule.

## Economics (ECON)

### ***ECON 5000 Special Problems*** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

### ***ECON 5001 Special Topics*** (LEC 0.0 and LAB 0.0)

This course is designed to give the department an opportunity to test a new course.

### ***ECON 5010 Seminar*** (RSD 0.0-6.0)

Discussion of current topics.

### ***ECON 5120 Advanced Micro and Macro Economics Essentials*** (LEC 1.5)

An introduction to the essentials of micro and macro economics for running a business. It is designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit in this course cannot be applied to any major or minor in Business, IS&T, or Economics. Additional case or report required. Prerequisite: Bachelor Degree.

### ***ECON 5310 Advanced Mathematical Economics*** (LEC 3.0)

Marginal analysis, calculus, and linear algebraic systems are applied in selected advanced topics in economics such as price theory, general equilibrium theory, input-output analysis, activity analysis, and game theory. This course is an advanced version of Econ 4310, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4310 and Econ 5310. Prerequisites: Econ 2100, 2200 and Math 1208, Math 3103.

### ***ECON 5330 Econometric Methods*** (LEC 2.0 and LAB 1.0)

A survey of econometric topics and methods illustrated through real world applications. Includes least squares estimation, generalized least squares, two-stage least squares, simultaneous equations models, panel data and qualitative choice models. Students will use modern statistical software packages (STATA, R) to perform hands-on quantitative analysis. Prerequisites: Econ 2100 and Econ 2200, Stat 3111 or Stat 3113 or Stat 3115 or Stat 3117 or Stat 5643.

### ***ECON 5337 Financial Mathematics*** (LEC 3.0)

The course objective is to provide an understanding of the fundamental concepts of financial mathematics. Topics include pricing, assets-liability management, capital budgeting, valuing cash flow, bonds, futures, swaps, options. Preparation for the financial mathematics actuarial exam will be provided. Prerequisites: Math 1215 or Math 1221, Econ 1100 or Econ 1200, and one of the following: Stat 3111, Stat 3113, Stat 3115, Stat 3117 or Stat 5643. (Co-listed with Math 5737).

### ***ECON 5342 Advanced Finance*** (LEC 3.0)

This course provides a rigorous and consistent presentation of the theory of financial decisions. Capital markets are analyzed under assumptions of risk aversion and uncertainty. Models of modern portfolio theory are discussed including the CAPM and the Modigliani-Miller analysis. This course is an advanced version of Econ 321, and will include additional research and project assignments. Credit cannot be obtained for both Econ 5160 and Econ 5342. Prerequisite: Econ 2100 or Econ 2200.

### ***ECON 5430 Advanced Cost-Benefit Analysis*** (LEC 3.0)

Investigates the rationale for cost-benefit analysis within a free enterprise setting. Discussion of market efficiency and failure; determination of social costs and benefits; applications of cost-benefit analysis; and, problems remaining in theory and practice. This course is an advanced version of Econ 4430, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4430 and Econ 5430. Prerequisite: Econ 2100.

### ***ECON 5532 Advanced Mining Economics*** (LEC 3.0)

Mining industry & national economics. Social & economics significance of mined commodities. Marketing of mined commodities. Innovation approaches to mine financing, project loans, and leasing. Mining feasibility studies, government influence & policy, mining industry foreign investment, investment strategies, mining taxation, cost predictions. Case Studies. (Co-listed with MIN ENG 5532).

### ***ECON 5644 Creativity, Innovation, and Sustainability*** (LEC 3.0)

This interdisciplinary course examines the use of innovation as a competitive technological strategy with a sustainability perspective. It explores ways in which individuals, groups, and organizations can become more creative and how leadership and a culture of change can be implemented.

### ***ECON 5710 Advanced International Trade*** (LEC 3.0)

Analysis of gains from trade; the effects of factor mobility; effects of trade restrictions on trade flow and income distribution; arguments for restricting trade; and effects of trade on economic development, employment and human capital development. This course is an advanced version of Econ 4710+D1194, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4710 and Econ 5710. Prerequisite: Econ 2100.

**ECON 5720 Advanced International Finance** (LEC 3.0)

Examination of the international monetary system, the Balance of Payments, the foreign exchange market, futures and options markets; foreign exchange and other risk management for firms, financing from a global perspective and direct foreign investment. This course is an advanced version of Econ 4720, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4720 and Econ 5720. Prerequisite: Econ 2200.

**ECON 5820 Advanced Labor Economics** (LEC 3.0)

Labor as a factor of production, collective bargaining, trade unionism, labor legislation, from the viewpoint of public policy. This course is an advanced version of Econ 4820, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4820 and Econ 5820. Prerequisite: Econ 2100 or Econ 2200.

**ECON 6000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ECON 6010 Seminar** (RSD 0.0-6.0)

Discussion of current topics.

**ECON 6337 Financial Mathematics II** (LEC 3.0)

Continuation of Math 5737/Econ 5337. Topics include martingales and measures, stopping times, discrete and continuous time finance, Brownian motion, Ito calculus, stochastic differential equations, Black-Scholes-Merton formula, numerical procedures. Prerequisite: Math 5737 or Econ 5337. (Co-listed with Math 6737).

**ECON 6440 Advanced Environmental and Natural Resource Economics** (LEC 3.0)

Optimum use of renewable and non-renewable resources, public goods and common resources, externalities, and quality of the environment; emphasis on public policy related to environmental and natural resource economics. As an advanced version of Econ 4440, it will include additional research assignments. Credit can't be earned for both Econ 4440 and 6440. Prerequisite: Econ 2100.

**ECON 6540 Advanced Energy Economics** (LEC 3.0)

Market structures. World resource development. Supply and demand analysis on energy production and consumption within domestic and global settings. This course is an advanced version of Econ 4540, and will include additional research and project assignments. Credit cannot be obtained for both Econ 4540 and Econ 6540. Prerequisite: Econ 2100.

**ECON 6641 Advanced Foundations of Sustainability** (LEC 3.0)

This interdisciplinary course is designed as an introduction to sustainability in commerce. It examines environmental, social, and economic issues in an organized context. Principles, processes and practices in sustainability will be explored. Project or written case study required.

**ECON 6642 Global Eco- and Social-preneurship and Innovation** (LEC 3.0)

This interdisciplinary course applies an entrepreneurial mindset to the environmental and social opportunities and challenges facing the global community. Topics are examined from multiple perspectives; nonprofit, hybrid, and for-profit organizations. Written case studies required. Research project required. Prerequisites: Econ 6641.

**ECON 6643 Advanced Ethical Problems in a Global Environment** (LEC 3.0)

Focuses on the international dimension of ethics including corporate responsibility from economic, social, and environmental perspectives. It addresses the ethical challenges of decision-making, stakeholder engagement, and governance at micro-(personal), and meso-(org), and macro-(systems) levels. Case studies will be included as part of the course.

## English (ENGLISH)

**ENGLISH 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ENGLISH 5001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ENGLISH 5100 Readings In Rhetoric And Composition** (LEC 3.0)

Directed readings and writing on selected topics and areas in Rhetoric and Composition. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

**ENGLISH 5210 Readings In British Literature** (LEC 3.0)

Directed readings and writing on selected topics and areas in British literature. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

**ENGLISH 5220 Readings In American Literature** (LEC 3.0)

Directed readings and writing on selected topics and areas in American literature. Credit will only be given for one of English 402, 403, 404, or 405 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

**ENGLISH 5230 Readings In Literature And Theory** (LEC 3.0)

Directed readings and writing on selected topics and areas in Literature and Theory. Credit will only be given for one of English 5210, 5220, 5230, or 5100 toward the Coop MA with UMSL. Prerequisites: Graduate standing and consent of instructor.

**ENGLISH 5571 Advanced Writing For Science & Engineering** (LEC 3.0)

Focus on writing applications specifically for students in scientific or engineering fields. Primary emphases will be on producing effective and readable professional writing. Prerequisites: English 3560 and 2560, or graduate standing.

**ENGLISH 5572 Advanced Writing For Science And Engineering II** (LEC 2.0)

This course – second in a series – focuses on writing for publication, from the initial proposal and query to the final product. Students will work on the materials they have underway with their advisers and/or research colleagues. Prerequisites: English 3560 and 2560, or graduate standing.

## Enterprise Resource Planning (ERP)

**ERP 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**ERP 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ERP 5110 Enterprise Resource Planning Systems Design and Implementation** (LEC 3.0)

This course provides a technical overview of Enterprise Resource Planning Systems and their impact on organizations. SAP is introduced to illustrate the concepts, fundamentals, framework, general information technology context, technological infrastructure, and integration of business enterprise-wide applications. Prerequisites: Preceded or accompanied by ERP 2110; or Graduate Standing and computer programming knowledge.

**ERP 5130 ERP in Small & Mid-Size Enterprises** (LEC 3.0)

Provides an overview of enterprise applications for small and midsize companies. A leading platform such as Microsoft Dynamics AX or SAP Business One is introduced to illustrate theories and practical enterprise-wide applications for entrepreneurs, who manage business functions across sales, operation, and financials, all in a single integrated system. Prerequisites: ERP 5110 or ERP 2110.

**ERP 5210 Performance Dashboard, Scorecard and Data Visualization** (LEC 3.0)

This course will study different performance management systems including dashboards, management cockpit, scorecards, and strategy maps in an organization. SAP's BW, Business Objects Xcelsius, Crystal Reports, Sybase Unwired Platform will be used to develop the applications.. Prerequisite: ERP 2110 or preceded or accompanied by ERP 5110.

**ERP 5240 Enterprise Application Development and Software Security** (LEC 3.0)

This course provides a conceptual foundation and hands on experience in web and mobile based (HTML5) applications development deployed through an enterprise platform. Enterprise development tools, such as SAP HANA Cloud Platform, will be used to build these apps. The course also covers software cybersecurity from a web and mobile perspective. Prerequisites: Programming knowledge and either ERP 2110 or preceded or accompanied by ERP 5110.

**ERP 5310 Supply Chain Management Systems in an ERP Environment** (LEC 3.0)

The course studies the need for supply chain integration and the challenges of managing complex interfaces using the systems approach for the planning, analysis, design, development, and evaluation of supply chain. SAP's ERP ECC, SCM, BW, and Sybase Unwired Platform are used to deploy SCM apps. Prerequisite: ERP 2110 or preceded or accompanied by ERP 5110.

**ERP 5410 Use of Business Intelligence** (LEC 3.0)

This course introduces data-oriented techniques for business intelligence. Topics include Business Intelligence architecture, Business Analytics, and Enterprise Reporting. SAP Business Information Warehouse, Business Objects, or similar tools will be used to access and present data, generate reports, and perform analysis. Prerequisites: IS&T 1750 or equivalent.

**ERP 5510 ERP System Administration** (LEC 3.0)

System administration and performance monitoring practices for an Enterprise Resource Planning (ERP) system will be studied. Students will install an instance of an ERP system and establish user management attributes and system security. Prerequisite: ERP 5110.

**ERP 6001 Special Topics** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

**ERP 6120 Enterprise Resource Planning: Systems Config and Integration** (LEC 3.0)

Implementation and design practices for business processes in Enterprise Resource Planning (ERP) systems. The course will examine and apply techniques used in SAP ERP system for system configuration and integration, with a focus on Financial Accounting, logistics, Controlling, and production. Prerequisite: ERP 5110.

**ERP 6220 Data Modeling & Visualization Prototyping for Enterprise Decision Dashboards** (LEC 3.0)

Study how to integrate data modeling and visualization prototyping in design and implementation of enterprise decision dashboards for descriptive, predictive, and prescriptive analytics. Assignments and project implementations use SAP HANA & BW, Design Studio, IBM Watson, and SAS Visual Analytics. Semester project prepared. Prerequisites: ERP 5110 and one of ERP 5410, ERP 6444 or IS&T 6444.

**ERP 6444 Essentials of Data Warehouses** (LEC 3.0)

This course presents the topic of data warehouses and the value to the organization. It takes the student from the database platform to structuring a data warehouse environment. Focus is placed on simplicity and addressing the user community needs. Prerequisite: IS&T 3423 or equivalent relational database experience. (Co-listed with IS&T 6444).

**ERP 6610 Advanced Customer Relationship Management in ERP Environment** (LEC 3.0)

Identification (targeting), acquisition, retention, and development (expansion) of (profitable) customers. Effective and efficient mgmt of customers, using IT. SAP CRM, SAS BI tools, and Sybase mobile application development are used. Research paper and presentation required. Prerequisites: ERP 2110 or preceded or accompanied by ERP 5110.

## Finance (FINANCE)

**FINANCE 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in finance. Prerequisite: Admission to the MBA program and permission of the instructor.

**FINANCE 5001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title. Prerequisite: Admission to the MBA program.

**FINANCE 5099 Research** (IND 0.0-9.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Permission of the instructor.

**FINANCE 5160 Corporate Finance II** (LEC 3.0)

This course provides a rigorous and consistent presentation of the theory of financial decisions. Capital markets are analyzed under assumptions of risk aversion and uncertainty. Models of modern portfolio theory are discussed including the CAPM and the Modigliani-Miller analysis. Prerequisite: Finance 2150 or equivalent basic corporate finance knowledge.

**FINANCE 5205 Graduate Finance Essentials** (LEC 1.5)

This course is an introduction to the essentials of corporate finance for running a business. This course is designed for students planning to enter the MBA program. Credit in this course cannot be applied to any major or minor in Business, Information Sciences and Technology. Additional case or report required. Prerequisite: Bachelor Degree.

**FINANCE 5260 Investments I** (LEC 3.0)

Introduction to fundamental elements of investment analysis. Students learn financial tools and gain necessary knowledge to select among alternative financial assets. Real world experience includes stock analysis, portfolio simulations and interactions with professionals in the securities industry. Prerequisites: Finance 2150 or equivalent basic corporate finance knowledge.

**FINANCE 5310 Financial Technology and Analytics** (LEC 3.0)

This course is built on finance theory, financial analysis, and quantitative methods from prerequisite courses. Students will design and construct integrated financial models. The objective is to offer students opportunities to experience hands-on numerical analyses, company valuation, and dynamic projections. Prerequisites: Finance 2150 or Graduate Standing.

**FINANCE 6001 Special Topics** (IND 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title. Prerequisite: Admission to the MBA program.

**FINANCE 6099 Research** (IND 0.0-6.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Permission of the instructor.

**FINANCE 6230 Advanced Mathematical Finance** (LEC 3.0)

Topics include exotic options, liquidity, volatility surfaces, discrete hedging, market jumps, calibrating to market, modeling yield curves and related products, convertible bonds, credit derivatives, various hybrid derivatives, applicable numerical methods. Prerequisite: Finance 2150.

## History (HISTORY)

**HISTORY 5003 Readings In American History Since 1865** (IND 3.0-5.0)

Directed readings and writing on selected topics and areas in American History since 1865. Prerequisites: Graduate standing and consent of instructor.

**HISTORY 5004 Readings In European History To 1715** (IND 3.0-5.0)

Directed readings and writing on selected topics and areas in European History to 1715. Prerequisites: Graduate standing and consent of instructor.

**HISTORY 5005 Readings In European History Since 1715** (IND 3.0-5.0)

Directed readings and writing on selected topics and areas in European History since 1715. Prerequisites: Graduate standing and consent of instructor.

## Marketing (MKT)

**MKT 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in marketing. Prerequisite: Consent of instructor required.

**MKT 5001 Special Topics** (LEC 0.0-6.0)

This is designed to give the department an opportunity to test a new course. Variable title.

**MKT 5099 Research** (IND 0.0-9.0)

Research investigation of an advanced nature leading to a major report suitable for publication in a journal or in a conference proceedings. Prerequisite: Consent of instructor required.

**MKT 5105 Graduate Marketing and Strategy Essentials** (LEC 1.5)

This course is an introduction to the essentials of marketing and strategy for running a business. It's designed for students planning to enter the MBA program who need this area and for non-business students who want some business background. Credit cannot be applied to any major or minor in Business, IS&T or Economics. Additional case study or report required. Prerequisite: Bachelor Degree.

**MKT 5310 Digital Marketing and Promotions** (LEC 3.0)

A managerial examination of integrated marketing communication (IMC) and creativity, with a focus on digital media and new marketing concepts. Specifically, we will look at innovative marketing techniques such as viral marketing, brand communities, experiential marketing and guerilla tactics. Prerequisites: At least Junior standing.

**MKT 5320 Marketing for Non-Profits** (LEC 3.0)

Illustrates the importance of creating synergy within a marketing campaign. Speaking with "one voice" allows a brand to make a stronger impact; students will work with a local non-profit to improve their marketing message at each customer touch point. Students will analyze a marketing plan and work to improve it, including brochures & donation letters. Prerequisites: At least Junior standing.

**MKT 6150 Advanced Customer Focus and Satisfaction** (LEC 3.0)

Major emphasis is given to the concept of customer focus, with coverage of techniques for obtaining customer needs, measuring customer satisfaction, developing products and services to satisfy customers, and maximizing the benefits of customer feedback. Individual focused research is included. Prerequisite: MKT 3110 or MKT 3105 or ENG MGT 3510. (Co-listed with BUS 6150).

**MKT 6580 Advanced Marketing Strategy** (LEC 3.0)

Identification and analysis of strategic managerial marketing issues. Integration of marketing concepts through theoretical overview and practical analysis, including extensive use of simulation. Independent work on marketing project. Prerequisites: MKT 3110 or MKT 6622 or ENG MGT 3510.

## Philosophy (PHILOS)

**PHILOS 5000 Special Problems** (IND 1.0-3.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PHILOS 5001 Special Topics** (IND 1.0-3.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

## Psychology (PSYCH)

**PSYCH 5000 Special Problems** (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

**PSYCH 5001 Special Topics** (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new graduate level course. Variable title.

**PSYCH 5010 Seminar for Industrial / Organizational Psychology** (RSD 3.0)

A seminar course for general overviews of the most recent research in Industrial-Organizational Psychology. Prerequisite: Graduate standing.

**PSYCH 5012 Ethics and Professional Responsibilities** (LEC 1.0)

Case studies examining the ethical practice of psychology in organizations will be discussed. This will include covering both the legal and ethical standards surrounding the consulting and practice of I-O psychology and personnel management in organizations. Prerequisite: Graduate standing.

**PSYCH 5020 Introduction to Industrial-Organizational Psychology** (LEC 3.0)

Review of the most recent theoretical and applied research in advanced personnel and organizational psychology. Topics will include personnel selection, training and performance appraisal, job attitudes, motivation, work groups and teams, leadership, organizational culture, and organizational development. Prerequisites: Graduate Standing.

**PSYCH 5040 Oral Examination** (IND 0.0)

(Variable) After completion of all other program requirements, oral examinations for on-campus M.S./PH.D students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

**PSYCH 5200 Theories and Practice of Psychological Measurement** (LEC 3.0)

An overview of psychological tests and batteries used in a variety of disciplines. An emphasis is placed on the proper development and use of these tests and test batteries. Tests examined will include tests of intelligence, aptitude, personality, and psychopathology. Prerequisite: Psych 4200 or graduate standing.

**PSYCH 5201 Psychometrics** (LEC 3.0)

An examination of statistical methods used to develop and refine measures of human performance, aptitudes, and personality. Topics include reliability and validity, data reduction, measuring inter-relationships among variables (e.g., factor analysis, multiple regression), and testing group differences. Prerequisite: Psych 5202.

**PSYCH 5202 Applied Psychological Data Analysis** (LEC 3.0)

This course will focus on those statistical methods most useful for advanced research in psychology. We will learn to use R, a powerful, open-source statistical programming platform, and work through examples with psychological data sets including such techniques as correlation, ANOVAs, regression, and chi-squared. Prerequisite: Graduate standing.

**PSYCH 5210 Advanced Research Methods** (LEC 3.0)

Research methods and techniques, with an emphasis on conducting psychological research in organizational settings. Topics discussed include: ethics, reliability and validity in measurement and application, proper uses of experimental, quasi-experimental, and survey methodologies, as well as advanced methodologies IRT, SEM, HLM, and Meta-Analyses. Prerequisite: Graduate standing.

**PSYCH 5600 Advanced Social Psychology** (LEC 3.0)

An advanced study of the behavior of individuals in interaction within groups. Consideration will also be given to the experimental literature dealing with the formal properties of groups, conformity and deviation, intergroup relations, and attitude formation and attitude change. Prerequisite: Psych 4600 or graduate standing.

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**PSYCH 5601 Small Group Dynamics** (LEC 3.0)

This course covers group perception, identification, leadership, structure, conflict, cohesion, commitment, performance, norms, roles, influence, and decisions, and groups' relations, networks, and work teams. Students consider both theory and applications to their lives and organizations through observational, research, team and applied assignments. Prerequisite: Psych 4601 or graduate standing.

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**PSYCH 5602 Organizational Development** (LEC 3.0)

Examination of the field of organizational development theories and interventions. An emphasis is placed on research methods and application of practices related to individual processes, group processes, and organizational structures and functions that impact change and development strategies and interventions. Prerequisite: Psych 4602 or graduate standing.

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**PSYCH 5603 Advanced Social Influence** (LEC 3.0)

An in-depth review of the principles and procedures that affect the process of social influence, with consideration given to attitudinal, compliance inducing, and perceptual influences. Students will consider the theoretical implications and practical applications of topics in social influence in the form of independent reading, research proposals and/or projects, and observational assignments. Prerequisite: Psych 4603 or graduate standing.

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**PSYCH 5700 Job Analysis and Performance Management** (LEC 3.0)

A focus on the scientific measurement of job performance. An in-depth discussion of the science and methods of appropriate job and task analysis will be discussed. Additionally, students will focus on current issues in performance management and appraisal including scientific findings related to both objective and subjective measures of performance. Prerequisite: Psych 4700 or graduate standing.

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**PSYCH 5710 Advanced Human Factors** (LEC 3.0)

An in-depth review of the foundations of human factors, focusing on the interaction of people with various forms of technology in a variety of environments. Topics include research and evaluation methods, displays (e.g., visual, auditory), attention and information processing, decision making, motor skills, anthropometry, and biomechanics. (Co-listed with ENG MGT 5330).

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**PSYCH 5720 Advanced Human-Computer Interaction** (LEC 3.0)

This course examines the psychological research and theories that contribute to the field of human-computer interaction. An emphasis will be placed on engaging in critical evaluation of research and applying theoretical knowledge to effectively use computers in organizations. Prerequisite: Psych 4720 or graduate standing.

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**PSYCH 5730 Environmental Psychology: Research and Practice** (LEC 3.0)

An in-depth review of the theoretical perspectives in environmental psychology and the psychological effects of various environments. An emphasis is placed on the review and integration of the research to explain the psychological issues related to various environments as well as to understand ways to effectively design living, educational, work, and recreational environments. Prerequisite: Psych 4730 or graduate standing.

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**PSYCH 6085 Internship** (IND 0.0-6.0)

Students will apply critical thinking skills and discipline specific knowledge in a work setting based on a project designed by the advisor and employee. Activities will vary depending on the student's background and the setting. Requires a major report. Prerequisites: Completed Core and Methods courses; instructor consent.

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**PSYCH 6099 Research** (IND 0.0-6.0)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisites: Consent of instructor required.

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**PSYCH 6602 Employee Affect and Behavior** (LEC 3.0)

Theory and research surrounding employee attitudes, emotions, and behaviors with an emphasis on antecedents and outcomes of: job satisfaction, engagement, organizational justice, trait and state positive and negative affect, organizational citizenship, counterproductive work, and proactive behaviors and the Implications for both employees and organizations. Prerequisite: Psych 5020.

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**PSYCH 6610 Leadership, Motivation, and Culture** (LEC 3.0)

Examination of research related to leadership, motivation, and the impact of organizational culture on organizational performance will be discussed. The course will focus on the application of psychological theories to enhance organizational functioning and to promote positive workplace behaviors. Prerequisite: Psych 5020.

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**PSYCH 6611 Leadership for Engineers** (LEC 3.0)

Provides engineers with a background in leadership concepts and principles; enables students to develop practical skills in leading and managing through multiple personal assessment. Topics include leadership styles, managing commitments, conflict resolution, change management, emotional intelligence, team dynamics and business ethics. Prerequisite: Eng Mgt 5110 or Psych 4602.

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**PSYCH 6700 Training and Development** (LEC 3.0)

Psychological theories of learning will be covered. Students will learn how evaluate training needs in an organization as well as how to subsequently develop, implement, and validate a training program in an organizational context. Prerequisite: Psych 5700.

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**PSYCH 6702 Personnel Selection** (LEC 3.0)

Current trends and methods in personnel recruitment and selection including classification, and promotion will be examined. An emphasis will be placed on legal and methodological considerations that can impact proper testing and assessment procedures. Cognitive abilities, personality, physical abilities, and other non-cognitive assessments will be discussed. Prerequisite: Psych 5700.

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## Speech & Media Studies (SP&M S)

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***SP&M S 5000 Special Problems*** (IND 0.0-6.0)

Graduate level problems or readings on specific subjects of projects in the department. Consent of instructor required.

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***SP&M S 5001 Special Topics*** (IND 0.0-6.0)

This course is designed to give the department an opportunity to test a new course with senior/graduate level emphasis. Variable title.

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***SP&M S 5010 Seminar*** (IND 0.0-6.0)

Advanced discussion of current topics.

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