Engineering, Ph.D.

About the Program
The College of Engineering offers a College-wide doctoral degree program. It is designed for students who have training in Engineering, Biological Sciences, Mathematics, or Physical Sciences, and who wish to carry out doctoral-level research in Engineering. Faculty members associated with the Ph.D. degree program are drawn from all departments in the College, representing a wide variety of technical backgrounds and interests. Because engineering research is an inherently interdisciplinary activity, graduates of the program have acquired a background in diverse engineering approaches that will promote their careers in research, academia, or industry.

Time Limit for Degree Completion: 7 years

Campus Location: Main

Full-Time/Part-Time Status: Students are able to complete the didactic portion of the Ph.D. degree program through classes offered after 4:30 p.m.

Interdisciplinary Study: Engineering research is highly interdisciplinary and draws on collaboration with members of the faculty and students within all departments of the College of Engineering, in the departments of Mathematics and the Physical Sciences, and within the School of Medicine.

Areas of Specialization: While the Engineering Ph.D. is inherently interdisciplinary, the student is admitted to the program in one of four departments and then conducts doctoral research within the home department. The areas of specialization are similar to those at the master's level:

- Bioengineering
- Civil and Environmental Engineering, including Civil Engineering Systems and Environmental Engineering
- Electrical and Computer Engineering, including Computer Architectures and Microelectronics, Digital Signal Processing and Digital Data Communication, and Intelligent Systems and Control
- Mechanical Engineering

Prospective students are strongly encouraged to communicate with members of the faculty about current areas of research.

Job Prospects: The program is primarily intended for individuals who wish to pursue careers in industry, government, and academia in a highly creative environment. The program is dedicated to producing engineers who will contribute to advancements in technology. In the past, most of the graduates of the Ph.D. in Engineering program have been employed in high-tech industries in research and development positions.

Non-Matriculated Student Policy: Up to 9 credits of graduate Engineering coursework may be taken at Temple University on a non-matriculated basis and subsequently applied to the Ph.D. degree upon admission. If the applicant's undergraduate GPA was less than 3.0, a GPA of 3.25 or better is required on this non-matriculated graduate coursework to receive an admissions exception. Consequently, the appropriate departmental Graduate Program Director may encourage those with an undergraduate GPA less than 3.0 to take their first three graduate courses prior to making formal application to the Ph.D. program. (See the relevant Graduate School policies on special admission procedures for non-matriculated students: 02.23.11.03 and 02.24.19.)

Financing Opportunities: Applicants for full-time study in the Ph.D. program are automatically considered for financial aid. Three forms of financial aid are awarded to Ph.D. students on a competitive basis:

1. Teaching Assistantship (TA): TA awards are made solely by the Department and require the awardee to work 20 hours per week in support of the Department's undergraduate programs. The TA is compensated with a 9-month stipend, a basic health-insurance plan, and 9 credits per term of tuition remission.
2. Research Assistantship (RA): Individual faculty confer RA awards, using their research funds, upon students who appear well-qualified to carry out the research. Typically, this faculty member becomes the RA's doctoral advisor. The RA normally works up to 20 hours per week and is compensated with a stipend, basic health insurance, and tuition remission.
3. Fellowships: Fellowships are awarded by the University in a competitive process that is open to all Ph.D. applicants. The appropriate departmental Graduate Program Director nominates exceptional Ph.D. applicants for a University Fellowship. Fellows receive 9 to 12 months of stipend, depending on the award; basic health insurance; and 12 credits of tuition remission each Fall and Spring term. Fellows of the University have no work obligations with respect to either the Department, the College, or the University.

Because financial aid is awarded on a competitive basis, applicants are urged to complete the application as early as possible.

Admission Requirements and Deadlines

Application Deadline:

Fall: March 1
Applications are processed on a continual basis. Ordinarily, the applicant is informed of an admissions decision within 4 to 6 weeks of receipt of all supporting application documents.

Applicants who plan to matriculate full-time are automatically considered for financial aid awards so no separate application for financial aid is required. To ensure financial aid consideration for the intended term of study, however, applicants should submit a complete application by January 15 (Fall) and August 1 (Spring).

Both admissions and financial aid award decisions originate in the various departments within the College of Engineering. Thus, it is vital that applicants designate their department of interest in their Statement of Goals. Indicate whether the application is to be considered by the Department of Bioengineering (BIO), Civil and Environmental Engineering (CEE), Electrical and Computer Engineering (ECE), or Mechanical Engineering (ME).

Further, applicants are encouraged to contact the appropriate departmental Graduate Program Director for advice and consultation in the application process. This assurance shall include identifying and providing contact information for departmental faculty who might share the applicant’s research interests. The applicant is encouraged to personally contact the identified departmental faculty for advice and information about her/his research in an effort to establish mutual areas of research interest between applicants and faculty.

Letters of Reference:
Number Required: 3
From Whom: Letters of recommendation should be obtained from college or research faculty who are familiar with the applicant’s competency. If the applicant has an established career in engineering, one of the letters should be provided by the applicant’s immediate supervisor. If the applicant has been out of school long enough that relevant academic reference letters appear impractical, s/he should contact the appropriate departmental Graduate Program Director to obtain a waiver of this admission requirement.

Coursework Required for Admission Consideration: Students not adequately prepared for advanced courses may be required to take a number of prerequisites. The department of application identifies the needed coursework on a case-by-case basis.

Master’s Degree in Discipline/Related Discipline: A master’s degree is not required, but preferred.

Bachelor’s Degree in Discipline/Related Discipline: A bachelor’s degree is required.

University regulations stipulate that the applicant must have earned a 3.0 grade-point average on a 4.0 scale in her/his undergraduate studies, but admission exceptions are made for a variety of circumstances. (See Graduate School Policy 02.23.11.03 (http://www.temple.edu/grad/policies/gradpolicies.htm).) The appropriate departmental Graduate Program Director helps the applicant navigate the admission possibilities and assists in the assessment of her/his overall educational qualifications with respect to the departmental requirements for the Ph.D. program.

Statement of Goals: Describe your relevant technical experiences, career goals, and specific research interests in one to two pages. Clearly identify the department of interest within the College of Engineering: Bioengineering (BIO), Civil and Environmental Engineering (CEE), Electrical and Computer Engineering (ECE), or Mechanical Engineering (ME).

Standardized Test Scores:
GRE: Required. Scores must be no more than 5 years in advance of the application date. (See Graduate School Policy 02.23.12 (http://www.temple.edu/grad/policies/gradpolicies.htm).) Applicants who require a waiver of the GRE should consult the appropriate departmental Graduate Program Director concerning the mechanics and consequences of obtaining an exception.

TOEFL: 79 iBT or 550 PBT minimum. (See Graduate School Policy 02.23.13.01 (http://www.temple.edu/grad/policies/gradpolicies.htm).)

Resume: Current resume required.

Advanced Standing: Both transfer credit for courses taken at another institution while matriculated at Temple and/or advanced standing credit for courses taken within the 5-year period prior to matriculating at Temple may be applied toward the Ph.D.-level didactic coursework requirement. Written approval is required from the student’s doctoral advisor, the College’s Associate Dean for Graduate Study, and the Graduate School. (See Graduate School Policy 02.24.21 (http://www.temple.edu/grad/policies/gradpolicies.htm).) Up to six credits of advanced standing for courses taken within the 5-year period prior to matriculating at Temple may be used to satisfy the master’s-level didactic coursework requirement. Approval of the appropriate departmental Graduate Program Director is required. The courses must be equivalent to courses offered at Temple in the student’s area of study and research, and the grades must be “B” or better.

Program Requirements

General Program Requirements:
Minimum Number of Credits Required Beyond the Bachelor’s. 60, including 30 credits of master’s-level didactic coursework¹, 15 credits of Ph.D.-level didactic coursework², and 15 credits associated with Ph.D. examinations and dissertation research.
Minimum Number of Credits Required Beyond the Master's: 30, including 15 credits of Ph.D.-level didactic coursework and 15 credits associated with Ph.D. examinations and dissertation research.

In the first term, the student and her/his departmental Graduate Program Director jointly determine the cohort that is appropriate for the student and initiate the "Ph.D. in Engineering Plan of Study." The Plan of Study form lists all required courses and suggests a Ph.D. program-requirement execution sequence for the student to follow. This form is used to track the student's progress, and is updated and annotated at least once a year as the student completes the various benchmarks in the Ph.D. program.

Note that, in general, students who want to take graduate coursework to satisfy either the Ph.D.-level or master's-level didactic coursework requirement in schools/colleges other than the College of Engineering need to obtain the appropriate written approvals on their Plan of Study form.

1 Master's-level didactic coursework may include up to, but no more than, 3 credits of ENGR 9182 Independent Study I or 3 credits of Directed Research (i.e., BIOE 9991, CEE 9991, ECE 9991, or MEE 9991).

2 Ph.D.-level didactic coursework may include up to, but no more than, 3 credits of ENGR 9282 Independent Study II. Typically, this coursework is selected by the student's Doctoral Advisory Committee and notated in the student's Plan of Study form.

Culminating Events:
Formation of the Doctoral Advisory Committee:
One of the student's first important tasks is to select a research advisor and form a Doctoral Advisory Committee. The Doctoral Advisory Committee selects the student's Ph.D.-level coursework and is responsible for guiding the progress of the student's dissertation research. The time frame for selecting a doctoral advisor depends on the student's level of preparation upon entering the Ph.D. program:

- Students admitted to the 30-credit cohort are sufficiently experienced to form their Doctoral Advisory Committee before the end of their second regular term of study.
- Students admitted to the 60-credit cohort ordinarily take one or two years of master's-level coursework before forming their Doctoral Advisory Committee by the end of their fourth regular term in the program.

See Graduate School Policy 02.28.11 (http://www.temple.edu/grad/policies/gradpolicies.htm) for clarification on the composition of the Doctoral Advisory Committee.

Preliminary Examination:
Whether the student is a member of the 30-credit cohort or the 60-credit cohort, s/he must complete all didactic coursework in her/his program of study prior to taking the preliminary examination. (See Graduate School Policy 02.27.11 (http://www.temple.edu/grad/policies/gradpolicies.htm).) Students in the 30-credit cohort ordinarily take the exam before the end of their third or fourth regular term. Students in the 60-credit cohort typically take the exam before the end of the eighth regular term.

The preliminary exam tests both the student's core knowledge in her/his engineering discipline and her/his capacity to synthesize and interpret research communications. The specific form, content, and frequency of the preliminary exam vary by department. Further, administration of the departmental preliminary exam is supervised by the departmental Graduate Program Director. Questions about the specific form and content of the examination should be directed, therefore, to the appropriate departmental Graduate Program Director.

The student should coordinate the scheduling of the preliminary exam with the appropriate departmental Graduate Program Director. Students have two opportunities to pass the preliminary exam and must register for one credit of ENGR 9994 Preliminary Examination Preparation in each term that the exam is attempted. Students are dismissed upon the second failure.

Dissertation Proposal:
Within one year of passing the preliminary exam, the student must develop a written research proposal and present it in an open College seminar. The student is responsible for scheduling the proposal and posting an announcement at least 10 business days in advance of this seminar. Ordinarily, the proposal seminar is immediately followed by a meeting of the Doctoral Advisory Committee in which the student is closely questioned about the details and strategy of her/his proposed research.

The proposed dissertation research is considered "approved" when the Graduate School receives the "Dissertation Proposal Transmittal for Elevation to Candidacy" form, found at http://www.temple.edu/grad/forms/, signed by all of the Doctoral Advisory Committee members. The student is considered to be a doctoral candidate after her/his dissertation proposal has been accepted by her/his Doctoral Advisory Committee and the signed transmittal form has been received by the Graduate School. (See Graduate School Policy 02.28.12 (http://www.temple.edu/grad/policies/gradpolicies.htm) for further procedural specifics.)

Research Credits:
Students carry out research throughout their studies and must register for research credits throughout the Ph.D. program. The type of research credits that a student registers for depends, however, on the student's progress in the Ph.D. program, specifically:

- In the terms prior to passing the preliminary exam, credit hours associated with the student's research should be registered under ENGR 9991 Directed Research.
• After the preliminary exam is passed, but before elevation to candidacy, credit hours associated with the student's research should be registered under ENGR 9998 Pre-Dissertation Research.

• After elevation to candidacy, the student's research credits should be registered under ENGR 9999 Dissertation Research. Students are required to register for at least two credit hours of ENGR 9999 Dissertation Research following their elevation to candidacy. (See Graduate School Policy 02.28.15 [http://www.temple.edu/grad/policies/gradpolicies.htm].)

Publications:
All doctoral students must publish at least two technical papers in refereed journals or refereed conferences. The papers must be based on the student's dissertation research, and the student must be first author. Paper writing and/or presentation at a conference is considered an integral part of the student's training. Also, peer review, in part, offers an indication of quality and novelty of the student's research.

Dissertation:
In the term that the student intends to defend her/his dissertation, the Dissertation Examining Committee must be formed. This committee consists of the original Doctoral Advisory Committee plus one additional “external” member who is not faculty in the College of Engineering. If the external examiner is not a member of Temple University’s Graduate Faculty, s/he must be approved by the Graduate School at least four weeks prior to the dissertation defense.

The Chair of the Dissertation Examining Committee is elected by all members of the committee at least three weeks prior to the defense; this elected Chair cannot be the student's doctoral advisor. The elected Chair of the Dissertation Examining Committee coordinates the proceedings of the defense and is responsible for the completion of all relevant College and Graduate School forms concerning the defense. The Chair of the Dissertation Examining Committee must be approved by the College's Associate Dean and is identified for the Graduate School in the student's official request to the Graduate School for permission to schedule the defense. (See Graduate School Policy 02.28.15 [http://www.temple.edu/grad/policies/gradpolicies.htm].)

The dissertation document should be prepared in a format compliant with University standards. (See Graduate School Policy 02.28.18 [http://www.temple.edu/grad/policies/gradpolicies.htm].) The student should provide her/his committee with a copy of the completed dissertation at least three weeks before the date of the dissertation defense.

The student must post a public announcement of her/his defense at least 10 business days prior to the defense. The announcement must be approved in writing by the Graduate School in advance of the posting. Note that any Graduate Faculty may request a copy of the dissertation in advance of the defense and may participate in the defense. (See Graduate School Policy 02.28.16 [http://www.temple.edu/grad/policies/gradpolicies.htm].)

The dissertation defense may be scheduled on any day in a term when classes are regularly held; it may not be scheduled on study days, during final exams, or over term breaks. Furthermore, if the student is to graduate in the same term that s/he defends the dissertation, the defense should be scheduled no later than 30 days prior to the end of the term to allow for document revisions in keeping with Graduate School deadlines, as specified at http://www.temple.edu/grad/documents/Dissertation-and-Thesis-Handbook.pdf.

The dissertation defense is an open University seminar in which the student presents the concepts and results of her/his research. This presentation is typically followed immediately by a meeting in which the Dissertation Examining Committee closely examines the student and her/his research. External attendees may participate in this closed portion of the defense with the permission of the Dissertation Examining Committee Chair. However, only members of the Dissertation Examining Committee may actually vote on the decision to accept the dissertation as prepared, accept the dissertation with revisions, or not accept the dissertation.

Contacts

Program Web Address:
http://engineering.temple.edu/additional-programs/phd-engineering

Department Information:

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ATTN: BIO or CEE or ECE or ME Program
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215-204-7800

Mailing Address for Application Materials:

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Bioengineering Courses

BIOE 5301. Biosignals. 3 Credit Hours.
This course offers a deep overview of the signals in the Biomedical fields. Signals are studied in several modalities, including time frame, frequency frame, and statistical frame. A deep analysis of filters and analysis tools is included together with some basic techniques of storing and pattern interpretation techniques. Furthermore, the course gives to the student the necessary knowledge to realize a complete Data Acquisition, Analysis and Logging using LabView as a tool. The laboratory activities include the development of a complete system to do acquisition, analysis, report and logging of data incoming from sensors.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOE 5311. The Entrepreneurial Bioengineer. 3 Credit Hours.
This course provides a practical overview of all stages of development of medical devices in regenerative medicine, from idea to launch of a company and commercialization of the product into international markets to address unmet medical needs. We will review the initial idea, based on an unmet medical need, review issues of intellectual property creation, determination of target markets, pre-clinical and clinical development, and different regulatory pathways leading to product approval and market introduction. We will discuss issues of company formation, financing and management, as well as target markets and avenues towards revenue generation. Note: Prior to fall 2017, the course title was "Entrepreneurial Studies in Regenerative Medicine - From Idea to Medical Practice".

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5321. Biosensors. 3 Credit Hours.
This course offers an in-depth overview of several sensors used in the Biomedical Fields. The sensors are analyzed from an engineering point of view going from the physical principles to the necessary filtering and linearization studying the characteristics of output signals. The course also gives the student the necessary basis for Data Acquisition using LabView as a tool. The laboratory activities include the connection of sensors, the study of amplification, linearization and interpretation of data.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5333. Applied Biospectroscopy. 3 Credit Hours.
This course introduces the basics of light propagation in tissue and other turbid media, vibrational spectroscopy, absorption and fluorescence, and emerging spectroscopic applications. Emphasis is on applications for assessment of biomolecules, engineered tissues and clinically-relevant analyses including musculoskeletal disease and cancer diagnosis. Multivariate analyses for complex spectral data sets will also be introduced.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5421. Capstone Elective: Bionanotechnology. 3 Credit Hours.
This course is intended for graduate students interested in acquiring knowledge involving nanometer-sized objects frequently utilized within the biomedical sciences and engineering areas. The aim of the class is to introduce fundamental concepts critical in the design, preparation, analysis, and usage of bionanotechnology (or nanobiotechnology) and its multiple bottom-up and top-down approaches. Multiple nanomaterials categories, such as nanoparticles, nanotubes, biomacromolecules, synthetic polymers, and self-assembled structures, will be covered in detail along with their applications.

Department Restrictions: Must be enrolled in one of the following Departments: Engineering:Bio Engineering.
Field of Study Restrictions: Must be enrolled in one of the following Majors: Bioengineering.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 5431. Neuroengineering. 3 Credit Hours.
This course will teach students how signals are generated and propagated in neurons and neuronal circuits, and how this knowledge can be utilized to engineer devices to assist people with neurologic disease or injury. The functions of neurons as discrete elements and as parts of neuronal assemblies will be examined; generator and action potentials; conduction in nerve fibers and across synaptic junctions; analysis of sensory and neuromuscular systems; EEG and EKG waveforms. At the completion of the course, students will have gained a fundamental understanding of neural interface/prosthetics design parameters from basic neural physiology to models of neural mechanisms. We will also review advanced neural interfaces currently being developed. The course will end with coverage of selected frontiers of neuroscience, including neurogenetic techniques, viral methods, and optogenetics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
BIOE 5441. Biomechanics. 3 Credit Hours.
Prerequisites: BIOE 2101 (Engineering Principles of Physiological Systems) with a minimum grade of C-, or BIOE 5737 (Systems Physiology for Engineers) with a minimum grade of B-, or equivalent course and BIOE 2312 (Mechanics for Bioengineering I) with a minimum grade of C-, or ENGR 2331 (Engineering Statics) with a minimum grade of C- and ENGR 2333 (Mechanics of Solids) with a minimum grade of C-, or equivalent course and BIOE 3312 (Mechanics for Bioengineering II) with a minimum grade of C-, or ENGR 2332 (Engineering Dynamics) with a minimum grade of C-, or equivalent course.

This course will provide students with an understanding of the mechanics of cells, tissue, and organ systems as well as methods for their analyses. Topics will include motion-actuating, force generating, and load-supporting mechanisms in the musculoskeletal system, as explained from basic engineering principles. We will also cover experimental and analytical approaches to designing load bearing implants and prosthetic devices.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
College Restrictions: Must be enrolled in one of the following Colleges: Engineering.
Repeatability: This course may not be repeated for additional credits.

BIOE 5451. Biomedical Imaging. 3 Credit Hours.
This course focuses on principles of diagnostic radiological imaging physics, including X-ray, computed tomography, and nuclear medicine, as well as optical imaging, ultrasound and magnetic resonance imaging modalities. The interaction of these modalities with tissues and detectors to produce useful image contrast will be presented, and students will gain an understanding of the basic physics of image acquisition and algorithms for image generation. Signal and noise characteristics, image quality and image reconstruction algorithms will also be covered. Image processing through MATLAB programming will be covered in class and in assignments.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOE 5461. Principles of Tissue Engineering. 3 Credit Hours.
This course will introduce fundamental concepts of tissue engineering and regenerative medicine, focusing biomaterials used for scaffolds, mechanisms of cell-biomaterial interactions, biocompatibility and foreign body response, cellular engineering, and tissue biomechanics. Principles of cell/developmental and stem cell biology will be introduced, which will enable the students to apply a multidisciplinary approach to engineering select tissues and organs, such as the musculoskeletal system, cardiovascular tissues, the nervous system, and to design artificial organs. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns. Note: Prior to fall 2017, the course title was "Principles of Tissue and Regenerative Engineering."

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

BIOE 5500. Special Topics in Bioengineering. 3 Credit Hours.
An emerging or advanced area of bioengineering research will be covered. Topics vary by semester.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may be repeated for additional credit.

BIOE 5501. Regenerative Engineering. 3 Credit Hours.
This course is a continuation of fundamental concepts introduced in Principles of Tissue and Regenerative Engineering focusing on developmental biology used in tissue engineering and regenerative medicine. Principles of cell development/biology, cell-cell interactions, signal transduction, and stem cell biology will be discussed with applications to regenerative medicine. These topics will also be discussed in the context of scale-up, manufacturing, ethical and regulatory concerns.

Department Restrictions: Must be enrolled in one of the following Departments: Engineering:Bio Engineering.
Field of Study Restrictions: Must be enrolled in one of the following Majors: Bioengineering.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(BIOE 5461|Minimum Grade of B-|May not be taken concurrently)
AND (BIOE 5721|Minimum Grade of B-|May not be taken concurrently)
**BIOE 5555. Biophotonics: Seeing is Believing. 3 Credit Hours.**

Only a small portion of the world around us is visible to the human eye. So, is there a way to visualize chaos, force, fractals, viral infection or cancer metastasis? Once we see biology happen, is the result a pretty image or a valuable measurement? Can the light be used to modify biological processes? In this course students will learn how photons are used to visualize and manipulate biomaterials at multiple scales. The first part of the course will provide a review of electromagnetism, light and optics. We will cover typical hardware used for imaging in biology, such as light sources, objectives and detectors used to generate images. Next, chemistry of imaging probes will be covered, including photochemistry and interaction of light and matter. The rest of the course will give a comprehensive overview of methodologies for multiscale imaging in life sciences, ranging from electron to atomic-molecular-cell-multicellular tissue-whole body scales, in vitro and in vivo. This will include among others Spectroscopy, Microscopy (Electron, Atomic, Fluorescent), Flow Cytometry, Optical Traps, Bioluminescence, X-Ray, MRI. Final classes will include special demonstrations in the imaging labs in the Temple Main Campus.

**Field of Study Restrictions:** Must be enrolled in one of the following Fields of study: Bioengineering.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5719. Introduction to Bioengineering. 3 Credit Hours.**

This course offers an introduction to biomedical engineering, a diverse and evolving field that integrates engineering principles, life sciences, clinical medicine, research and engineering design, with the overall goal of improving health care and quality of life. Professors with expertise in specific fields of biomedical engineering will present lectures and discussions on a broad range of topics, including tissue engineering and regenerative medicine, biomaterials, biomechanics, bioinstrumentation, biomedical imaging and optics, and signal processing.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5721. Cell Biology for Engineers. 3 Credit Hours.**

This course introduces biological concepts in modern cellular and molecular biology to engineering students. Topics will include the chemical composition of cells, bioenergetics and metabolism, structure and function of the plasma membrane, transport across membranes, the cytoplasmic membrane system, the extracellular matrix, interactions between cells and their environment, the cytoskeleton and cell motility, sensory systems, and cell signaling. In addition, an introduction to basic anatomy and physiology of vertebrates will include the skeletal system, muscle system, cardiovascular system, and nervous system.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5737. Systems Physiology for Engineers. 3 Credit Hours.**

Systems Physiology is designed for graduate students majoring in engineering and for others interested in studying physiological processes from the molecular level to the organ/systems level. Among the topics covered are: scaling, respiration, circulation, cardiac process, renal function, muscle function, neuromuscular junction, neural processes, and temperature regulation. The course stresses the application of energetic and informational principles to the study of the body.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**BIOE 5741. Biomaterials for Engineers. 3 Credit Hours.**

This course introduces engineering students to materials as they interact with biological systems, primarily in medicine. Topics will include a review of properties of materials, the classes of materials, tissues that come into contact with materials, the degradation of materials in the biological environment, the application of materials for specific uses, tissue engineering, and biomaterials standards and regulations.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
BIOE 5999. Research Experience in Bioengineering. 0 Credit Hours.
Research Experience provides graduate students laboratory experiences/research practices prior to undertaking independent, directed, master project, master’s thesis, or dissertation research. This course allows graduate students the opportunity to learn to use laboratory equipment, designing and carrying out an experiment(s), collecting preliminary data, field experiences, and participation in laboratory meeting, etc. with faculty which may lead to identifying a faculty mentor. The course will be graded as Pass or Fail. The Research Experience is a non-repeatable course. After the completion of this Research Experience course, students will need to be enrolled in independent study, directed research, master’s research, master’s thesis, dissertation proposal, or dissertation if they continue in an active research program.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

BIOE 9182. Independent Study. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9991. Directed Research. 1 to 3 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9994. BioEngineering Preliminary Examination Preparation. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9995. BioEngineering Project Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9996. BioEngineering Thesis Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9998. Bioengineering Pre-Dissertation Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

BIOE 9999. BioEngineering Dissertation Research. 1 to 6 Credit Hour.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

Civil Engineering Courses

CEE 5048. Probability and Statistics in Engineering. 3 Credit Hours.
This course is designed to build a conceptual background in probability, statistics, and stochastic analysis. It prepares the graduate student for research in uncertainty analysis and stochastic models in engineering. It begins by building a solid integrated background on the subjects that conform uncertainty analysis in engineering: probability, statistics, and stochastic modeling. The theory is complemented with numerous exercises of application in engineering uncertainty analysis, and with computer simulations using modern computer algebra software, such as MAPLE. Students are gradually taken to more advanced subjects and eventually to the analysis of differential equations subject to random initial conditions, random forcing terms, and random parameters. Partial differential equations and nonlinear stochastic equations are treated.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5058. Probability Statistics in Engineering. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5110. Special Topics. 3 Credit Hours.
Special topics courses are developed to cover emerging issues or specialized content and they do not repeat material presented by regular semester courses.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may be repeated for additional credit.

CEE 5201. Transportation Systems Management. 3 Credit Hours.
This course covers cost-effective techniques for the rebuilding of deteriorated transportation systems; pavement management and traffic systems management; extensive use of advanced computer software packages.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5202. Transportation Engineering. 3 Credit Hours.
This course focuses on the principal modes of transportation, including highway, rail, and air; analysis of elements of transport technology; and transportation system development, planning, design, construction, and maintenance.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5203. Structural Design of Pavements. 3 Credit Hours.
This course covers basic characteristics of different pavement structures; various modes of failure and design of pavement structures; identification and analysis of stresses; strains and deflections in flexible and rigid pavements; computation of traffic loading and volume for the structural design of pavements; engineering properties of pavement materials; pavement performance and distress; and empirical and mechanistic-empirical approaches.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5211. Bridge Design. 3 Credit Hours.
The course covers bridge design in structural steel and reinforced concrete; application of AASHTO bridge design specifications; and analysis techniques for complex structures. Preliminary designs include investigating alternative structural systems and materials. Final designs include preparation of design calculations and sketches.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5212. Transportation Engineering Materials. 3 Credit Hours.
Topics include physical properties of asphalt, aggregates, portland cement, portland cement concrete, and their combinations; advanced techniques in material characterization in the lab and the field; material variability, sampling, and statistical techniques; and the impact of these properties on their characterization of the design, construction, rehabilitation, and management of transportation facilities, including portland cement concrete pavements with steel reinforcement; construction methodologies, recycling, and energy consideration; and application of the state-of-the-art computer software packages.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5221. Intelligent Transportation Systems. 3 Credit Hours.
Coverage embraces the multidimensional upgrades needed for highway and vehicles for developing intelligent transportation systems. Contributions from important related fields such as telecommunications, safety, management, urban and regional planning, and economics where they interface with transport are included. Several case studies constitute an integral part of the course.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.
CEE 5231. Airport Engineering. 3 Credit Hours.
This course deals with the various aspects of airport engineering, planning, design and development of 21st century airports. The course covers airport master and system planning, airside layout, landside access design, passenger and cargo facilities, terminal design, drainage and pavement design.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5241. Pavement Management and Traffic Systems Management. 3 Credit Hours.
The course covers development of management methods for analysis, planning, design, construction, maintenance, and rehabilitation of pavements and traffic systems. The objective functions include creation of more efficient use of existing facilities through improved management and operation of vehicles and roadway.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5244. Introduction to Geosynthetics. 3 Credit Hours.
This course will enhance your critical understanding of Geosynthetic Materials used in civil engineering applications and develop the knowledge and skills required for designing and applying geosynthetic materials in civil engineering and environmental applications. Geosynthetics properties, testing of properties, design of geotextile, geogrids, geonets, and geomembranes for applications in separation, pavement design, embankment and retaining wall reinforcement, soil stabilization, filtration, drainage and liquid barrier, construction guidelines and case histories. The module will also develop critical understanding of the processes and materials used for the manufacture of geosynthetic materials.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5251. Pavement Rehabilitation and Maintenance. 3 Credit Hours.
The course covers fundamental behavior of materials used in building pavements. These materials include aggregate mixtures, asphalt binders and mixtures, and Portland cement concrete. The course covers methods of field construction and quality control of materials and their impact on long term performance. The course helps students understand the role of material properties in design of pavements including cost analysis. Students will learn testing methods, selection criteria, and standard specifications. Finally, the students will use accumulated knowledge through the course to understand strategies of pavement rehabilitation and maintenance. Principles of asset management will be introduced in the course to optimize maintenance and rehabilitation interventions for improving longevity.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5301. Construction Administration. 3 Credit Hours.
The course focuses on the engineering and construction industry; the basis of construction contracting; organizational structure and its functions; management structure and its functions; office administration, employment practices, and labor relations; organizational financing and accounting; and safety practices, risk management, and industrial insurance.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5302. Engineering Project Management. 3 Credit Hours.
This course provides an overview of the basic principles underlying all methods of project management, including project estimating, planning and scheduling, budgeting, cost accounting and cost control, project documentation, tracking and resource leveling. It also focuses on utilization of project management software packages for selected civil engineering projects; different types of projects; organizing the project management functions; setting up the project team; starting up and managing engineering projects; and ensuring the effective completion of the project on time, within budget, and meeting specifications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5303. Construction Financial Management. 3 Credit Hours.
Coverage includes project development in construction, project budgeting and job costing approaches, cost management and financing alternatives, evaluation of financial and accounting objectives required with each project, forecasting cash needs and profit, and financial reporting procedures.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5312. Construction Equipment Management. 3 Credit Hours.
This course focuses on the concepts and theories of construction equipment operation, ownership costs, and their relationship to production systems; analysis of depreciation and fixed costs for equipment pricing on construction projects; selection and use of construction equipment; and equipment economics and financing.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5321. Geotechnical Engineering. 3 Credit Hours.
This course deals with soil testing, site investigation, design of shallow and deep foundations, earth retaining structures, and advanced topics in soil behavior and stability.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5411. Structural CADD Systems. 3 Credit Hours.
Topics include behavior and analysis of simple and complex structures subjected to dynamic loads; using exact and approximate analytical techniques; determination of free response and force response using modal superposition and numerical integration; review of the characteristics of earthquakes with consideration of site and structural parameters on the response of buildings; and application of analysis and design procedures required to achieve earthquake-resistant structures in accordance with building code specifications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5421. Structural Dynamics. 3 Credit Hours.
This design course addresses developments in theory and practice of earthquake engineering. It familiarizes students with new techniques of analysis and seismic design. Students learn advanced concepts in applied mathematics, especially structural dynamics and application of seismic building and bridge codes. Familiarity with differential equations, matrix methods of analysis, non-linear equations, eigenvalue solutions, and finite elements modeling are required. Students are instructed to learn and apply new software for dynamic analysis. Laboratory work includes the study of experimental models such as for bridge piers (frames, walls, and hammerhead columns) using an MTS machine for applying dynamic loads.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5431. Behavior and Design of Steel Structures. 3 Credit Hours.
The course's design objective is to develop within the student an awareness of the fundamentals required to produce safe, functional, and economical steel structures, which are in conformance with national building codes and industry specifications and standards. This is an advanced course in structural engineering intended to develop professional-level competence in the design of steel-framed buildings, utilizing the most up-to-date design code.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5432. Structural Mechanics. 3 Credit Hours.
Topics include principles of mechanics and stress and strain at a point; analysis of statically determinate and indeterminate structures with static and moving loads using energy methods and force and deformation methods; beam theory, shear center, unsymmetrical bending, introduction to numerical methods, and computer techniques; and introduction to the use of the GT-STRUDAL and ANSYS computer programs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5433. Behavior and Design of Masonry Structures. 3 Credit Hours.
Coverage includes the fundamental principles of masonry behavior and design. In this course, up-to-date information about material testing, research methodology in the area of masonry structures, and codes are presented. The first part of the course presents the fundamental behavior and characteristics of masonry materials and masonry assemblages, the deformational characteristics of brick and block masonry, performance of load-bearing wall systems and shear wall system, the design of unreinforced and reinforced masonry elements, and the construction details of masonry structures. The second part of the course concentrates on the seismic resistance of masonry structures, prestressed masonry, and applied design of low and high-rise buildings.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5434. Behavior and Design of Reinforced Concrete Structures. 3 Credit Hours.
Behavior, analysis, and design of advanced reinforced concrete structures and components including columns subjected to flexure in one or two direction, slender columns, floor systems including two-way slabs, and analysis, design application using modern software.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5445. Earthquake Engineering and Seismic Design. 3 Credit Hours.
Basic knowledge of and introduction to earthquake engineering, seismic design and analysis methods, and seismic design based on International Building Code (IBC), ASCE 7 - Minimum Design Loads for buildings and other structures, introduction of material specific design requirement.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5531. Life Cycle Assessment and Carbon Footprinting. 3 Credit Hours.
Life Cycle Assessment (LCA) examines the environmental impacts of products, processes and policies beyond their direct production. Cradle to grave analysis in this manner provides the full picture that is needed to understand the true impact. This course provides an overview of Life Cycle Assessment principles and practice in relation to environmental and energy concerns. Regulatory and economic decision support tools and software analysis packages will be included. The course is structured such that students will start an LCA from the beginning of the course and progress on it as topics are covered.

Field of Study Restrictions: Must be enrolled in one of the following Majors: Civil Engineering, Electrical Engineering, Mechanical Engineering.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5621. Engineering Hydrology. 3 Credit Hours.
Quantifying water flow in watersheds is a crucial step in the design of environmental facilities, such as drinking water treatment plants, and in delineating floodplains. This course deals with the water cycle over watersheds by addressing the motion of water masses in the atmosphere and in surface and subsurface systems. Students who successfully pass this class are able to deal with most hydrology problems treated in the industry sector.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5622. Fate of Pollutants in Subsurface Environments. 3 Credit Hours.
This course focuses on integrated chemical, physical, and microbiological principles of contaminant fate and transport processes necessary in the use of engineered approaches toward selecting and implementing subsurface cleanup options. It also covers abiotic processes, biotic processes, empirical models, and vulnerability mapping.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5623. Contaminant Dynamics in Urban Streams. 3 Credit Hours.
This course will focus on environmental systems near the air:water and water:sediment interfaces. These systems are by definition boundary or edge systems and are therefore exceptionally important to aquatic ecosystem functioning. After briefly discussing the air:water interface in rivers and lakes, the course will focus on the water:sediment interface. It is here that steep gradients in chemical concentration can be found and significant nutrient cycling occurs. In addition, studies have shown that significant ecosystem productivity and respiration occurs within the bed sediments of flowing water. The course will discuss the concept of transient storage and hyporheic exchange; issues surrounding modeling of transient storage and hyporheic exchange; phosphorus and nitrogen biogeochemistry within the hyporheic zone; and biotic/abiotic nutrient cycling.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5631. Environmental Hydrology. 3 Credit Hours.
Topics include the physics of surface and subsurface circulation and storage of water and the transport of contaminants in watersheds, soils, aquifers, rivers, the ocean, and the atmosphere, as well as the laws and equations that govern the recharge, flow, storage, and discharge of water in natural environments. Emphasis is given to qualitative analysis and quantitative evaluation methods of the different hydrologic processes with potential applications in surface and groundwater resources engineering, and environmental analysis. Analytical and numerical procedures to solve the arising equations are presented, along with the most commonly used models to solve water resources problems. Also studied are engineering methods for the sustainable use of water resources; engineering methods for the containment and treatment of surface and groundwater pollution; and the restoration of aquifers.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5641. Urban Streams and Stormwater Management. 3 Credit Hours.
Stormwater management has become a significant issue in recent years. In the past, the typical thinking was "get it out of my town," which resulted in downstream communities suffering the brunt of poor or inadequate management. In fact, only the rate of runoff was addressed, not the volume nor the quality of that runoff. In urban areas, the volume of runoff increases significantly due to additional impervious cover (e.g., pavement and rooftops), and urban stormwater runoff causes water quality degradation due to excess amounts of nutrients, metals, bacteria, and sediment. This course addresses the impact of improperly controlled runoff on urban streams and how the rate, volume, and quality of urban stormwater runoff can be properly controlled through appropriate Best Management Practice (BMP) implementation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5701. Physical Principals of Environmental Systems. 3 Credit Hours.
Basic principles of process engineering as they relate to pollution control are studied, including heat and mass transfer; mixing, chemical, and biological reactions; and reaction and kinetics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5702. Chemical Principles of Environmental Systems. 3 Credit Hours.
This course focuses on the essential chemical principles necessary to understand the nature of commonly occurring pollution problems and engineering approaches to their solutions; thermodynamics, chemical equilibria, acid-base chemistry, carbonate system, Redox chemistry, and adsorption/desorption phenomena.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5703. Mathematical Modeling. 3 Credit Hours.
This introductory graduate course focuses on numerical modeling of engineering systems. It covers standard mathematical techniques, such as interpolation, numerical integration, numerical solutions of ordinary and partial differential equations, parameter estimation, and optimization. Students will have to use an algorithmic programming language, such as Matlab, Fortran, or C++.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5711. Air Pollution Control. 3 Credit Hours.
Topics include theory and principles of the design and operation of the major categories of air pollution control equipment, and an introduction to dispersion modeling. An extensive design problem is a major course component.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5721. Weather Monitoring and Forecasting. 3 Credit Hours.
This online course will offer a basic understanding of measurements of the atmosphere used for weather analysis and forecasting. Data from instruments such as weather balloons, radar, lightning mapping arrays, and satellites will be included. Special emphasis will be on interpreting satellite imagery and use in weather forecasting and warnings. Students will have the opportunity to learn to interpret real-time data online, and to make their own weather forecasts. The course will be taught primarily online, though one or two on-campus meetings may be required during the semester.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5731. Solid Wastes Engineering. 3 Credit Hours.
Coverage includes engineering principles of solid waste generation, characterization, collection and transport, separation, source reduction and recycling, and physical chemical and biological treatment strategies.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5761. Environmental Chemistry. 3 Credit Hours.
This is an advanced course focusing on examination of processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. The lectures will begin with intermolecular interactions and thermodynamic principles governing the kinetics of some of the important chemical and physicochemical transformation reactions of organic contaminants. From this class, students will learn to predict chemical properties and to apply the knowledge of chemical properties and transformation reactions to assess the environmental fate of organic contaminants.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5762. Environmental Organic Chemistry. 3 Credit Hours.
This is an advanced course focusing on examination of processes that affect the behavior and date of anthropogenic organic contaminants in aquatic environments. The lectures will focus on intermolecular interactions and thermodynamic principles governing the kinetics of some of the important chemical and physiochemical transformation reactions of organic contaminants.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5771. Chemistry for Environmentally Sustainable Engineering. 3 Credit Hours.
This course is a survey of environmental chemistry as it relates to the development of environmentally sustainable engineered systems.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

CEE 5772. Sustainable Development and Industrial Ecology. 3 Credit Hours.
As an introduction to the concepts of industrial ecology and sustainability, the course focuses on an interdisciplinary framework for the design and operation of industrial systems as living systems interdependent with natural systems.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
CEE 5773. Sustainability Aspects of Water Supply and Wastewater Treatment. 3 Credit Hours.
Major environmental, economic and social trends are influencing the application of sustainability principles within the engineering profession. This course will examine the sustainability principles that will transform future engineering practice regarding drinking water supply and the treatment of wastewater. The term, wastewater, will be replaced by one more representative of the fact that ‘wastewater’ is in fact a largely untapped source of raw materials. It is in the areas of energy recovery, small molecule harvesting, and the water energy nexus where the next generation of environmental engineers will have a major impact on meeting societal needs regarding the provision of adequate drinking water as well as industrial requirements for this increasingly scarce resource. The course will introduce the underlying principles of sustainability directly relevant to meeting this need. Case studies will evaluate the above mentioned principles and the applicable areas of energy, chemical intermediates, and reclamation of previously used water, with a focus on dealing with emerging microconstituents in the water environment.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5774. Membrane Separation in Wastewater Treatment. 3 Credit Hours.
The course describes in detail membrane separation technology for a wide range of applications including water treatment and desalination. The course covers: global water shortages and need for membrane technology, microfiltration, ultrafiltration, nanofiltration and reverse osmosis membrane processes and current applications in water treatment, operational and energy issues, limitations, fouling and membranes processes coupled with biological treatment. The course is valuable as a prerequisite to more advanced research in environmental engineering, as a technical education to stimulate graduate students’ interest in environmental sustainability, and as an introduction to environmental constraints that are increasingly important to other engineering disciplines.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5792. Biological Principles of Environmental Systems. 3 Credit Hours.
Applications of biological processes in environmental engineering are historic and eminently modern, from traditional ones like activated sludge and anaerobic digestion to emerging applications like detoxification of hazardous chemical and biofiltration of drinking water. This course is designed to identify the biological principles essential for the understanding and designing of biological processes used for environmental protection and improvement. While many biological processes are being employed and developed by environmental engineers, there is no place in the standard civil engineering curriculum for detailed discussion on the underlining principles and their applications. This course emphasizes the comprehension of theoretical concepts and their application in a variety of situations. It covers the fundamental biological principles by their practical applications in engineered and natural environments.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5793. Environmental Biotechnology. 3 Credit Hours.
Biotechnology plays a central role in environmental science and engineering, including wastewater treatment, pathogen control, and biodegradation. The objective of the course is to provide environmental engineers and scientists with advanced concepts and quantitative tools that are necessary for understanding environmental processes and designing environmental protection systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 5794. Advanced Biological Wastewater Treatment. 3 Credit Hours.
Biological processes play a central role in wastewater treatment and are used in every wastewater treatment plant to remove organic compounds, nutrients, and other compounds from the water before discharging it back to the environment. The objective of the course is to provide environmental engineers and scientists with advanced concepts and quantitative tools necessary for understanding environmental processes and designing environmental treatment systems related to wastewater including advanced aerobic and anaerobic processes. The course integrates the use of microbiological principles into engineering wastewater treatment process. The course will provide a better understanding of interesting and complex environmental topics related to sustainable environmental remediation and protection. The course is valuable as a prerequisite to more advanced research in environmental engineering, as a technical education to stimulate graduate students’ interest in environmental sustainability, and as an introduction to environmental constraints that are increasingly important to other engineering disciplines.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
CEE 5795. Aquatic Toxicology in Environmental Engineering. 3 Credit Hours.
This course provides an introduction to the basic concepts of toxicology necessary to understand the effects of contaminants in the water environment. Specific topics include sources and classes on aquatic contaminants, environmental chemistry that influences behavior in the aquatic environment, the disposition and metabolism of these substances that affect their toxicity, and the physiological response of exposure in aquatic species and humans. The course will provide an overview of aquatic toxicity testing methods and application of toxicity data in the risk assessment of aquatic exposures to emerging contaminants, such as pesticides, pharmaceuticals, and natural products. Case studies will cover historical and contemporary examples of contaminant-driven effects.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5799. Environmental Engineering. 3 Credit Hours.
This course focuses on the generation, transport, effects, and control of environmental pollution within and across media, as well as problem analysis and control design. Theoretical development is augmented with applications of state-of-the-art software packages. Students complete a term project.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5811. Advanced Soil Mechanics. 3 Credit Hours.
Advanced concepts related to behavior of soil as an engineering material. Topics include consolidation magnitude and time rate, evaluation of secondary compression, mitigation of consolidation of settlements, shear strength of soils and other geologic materials, principles of critical state soil mechanics, and normalization of undrained shear strength.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5821. Foundation Engineering. 3 Credit Hours.
Principles of foundation engineering and design. Topics include soil stress distributions, bearing capacity of shallow (footings, mats) and deep foundations (driven piles, drilled shafts), tolerable settlements, construction techniques, and field quality control.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5822. Earth Retaining Systems. 3 Credit Hours.
Principles related to design of earth retaining systems and stability of earth slopes. Topics include lateral earth pressure theory, temporary and permanent retaining structures, in-situ reinforcement, and braced evacuations. Shear strength of cohesive and granular soils and slope stability analysis using limited equilibrium, design charts and numerical methods.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 5823. Geotechnical Earthquake Engineering. 3 Credit Hours.
An introduction to seismology and earthquake hazards in geotechnical engineering. Topics include plate tectonics and earthquake faulting, strong ground motions, dynamic soil properties, and characterization of design ground motions based on deterministic and probabilistic seismic hazard analysis. Analysis of earthquake-induced ground failures, seismic design of earth retaining systems and slopes, and effects of soil-structure interaction.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

CEE 8302. Advanced Project Management. 3 Credit Hours.
This course covers analysis of project control, job budgeting and costing, safety and risk management, bidding strategies and management, construction information management, and case studies of construction projects and company profiles.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.
CEE 8701. Advanced Physical/Chemical Treatment Processes. 3 Credit Hours.
There are numerous sites in the environment where surface water, ground water or soil is contaminated with toxic chemicals. In addition, many industrial wastewater and air emissions contain toxic chemicals which required treatment. Due to the chemical toxicity, we rely on physical and chemical processes for the decontamination of the fluid stream. Some of the commonly used treatment technologies are carbon absorption, air stripping and scrubbing. Of late, advanced oxidations processes have been examined and implemented as well. These processes are also used to produce high quality drinking water. The course deals with the analysis and design of some commonly used advanced physical/chemical processes for treatment of contaminated water and air. This course complements, and builds upon the fundamental science discussed in other courses in the curriculum on physical and chemical principles. In this course, emphasis will be placed on understanding the basic science, and the engineering design principles. Treatment of water, wastewater and air using processes such as air stripping, scrubbing, carbon absorption and advanced oxidation processes will be discussed, and design of the treatment systems will be conducted.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 8702. Advanced Chemical Principles of Environmental Systems. 3 Credit Hours.
This is an advanced course focusing on examination of processes that affect the behavior and fate of anthropogenic organic contaminants in aquatic environments. The lectures will focus on intermolecular interactions and thermodynamic principles governing the kinetics of some of the important chemical and physiochemical transformation reactions of organic contaminants.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 8703. Computer Modeling of Environmental Transport. 3 Credit Hours.
Topics include theory and computer modeling of transport and diffusion within and across media; and application of models to problems of air, water, and soil pollution with case studies.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 8751. Water and Wastewater Systems Design. 3 Credit Hours.
This course covers the design of water distribution and sewage handling facilities, including sewers, pumping stations, seepage beds, septic tanks, spray irrigation, and natural treatment systems, such as overload and swamp treatment.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

CEE 9182. Independent Study I. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by MS/MSE students and once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, the student conducts independent research on a selected topic in engineering.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
CEE 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have completed their coursework but who have not yet passed both the Ph.D. Preliminary Examination.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9995. Project. 1 to 3 Credit Hour.
A project is assigned with the approval of the Civil and Environmental Engineering Graduate Committee and conducted under the supervision of a graduate faculty advisor. An oral presentation in an open seminar and a written report are required to complete the independent project. Projects related to industrial applications are encouraged. For non-thesis students only.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9996. Thesis. 1 to 3 Credit Hour.
Master’s thesis. May be taken twice.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9998. Pre-Dissertation Research. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have passed both the Preliminary and Qualifying Examinations but who have not been elevated to candidacy.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

CEE 9999. Dissertation Research. 1 to 6 Credit Hour.
This course is intended only for those students who have achieved Ph.D. Candidacy status. A minimum of 6 semester hours is required for graduation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Student Attribute Restrictions: Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

Repeatability: This course may be repeated for additional credit.

Electrical Engineering Courses

ECE 5022. Engineering Analysis and Applications. 3 Credit Hours.
Vector space, basis, projection, null space, function space, L2 and space of continuous functions, Hilbert space, orthogonality, generalized Fourier series, linear transformation, adjoint transformation, eigenvalue problem, linear functional, Gateaux and Frechet differential, constrained optimization, infinite dimensional systems, complex analysis.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5033. Probability and Random Processes. 3 Credit Hours.
Sets and events, Random variables, Distribution and density functions, Functions of multiple random variables, Moments and conditional statistics, Information entropy, stochastic processes, wide-sense stationary process, ergodicity, correlation, and power spectrum of stationary processes. Applications to sampling theory and signal modulation and detection.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5116. Spacecraft Systems Engineering. 3 Credit Hours.
The concept of systems engineering is introduced using a satellite application. Systems engineering is a top-down approach to the design, implementation, testing, and deployment of large-scale systems to meet the needs of users. The topics will include systems engineering methodology, dynamics of spacecraft, and celestial mechanics. This course will also introduce the notion of invention and innovation, and how they are related to the intellectual property issues.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
ECE 5314. Microelectronics. 3 Credit Hours.
Advanced study of electronic devices and their applications to linear, non-linear, and digital circuits; transistors, FET’s, amplifiers, digital integrated circuits, and VLSI’s; Software design emphasized. A term project will be assigned.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ECE 5324. VLSI System Design and Testing. 3 Credit Hours.
An introduction to a hierarchical design methodology of VLSI; study of basic logic elements and design methods in nMOS and CMOS; development of testable designs; the physics of MOS devices and fabrications processes; design rules and computation of circuit parameters from layout; system level design techniques; circuit structures with built-in self-test, design-for-test and self-checking features.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5314|Minimum Grade of C|May not be taken concurrently.

ECE 5412. Control System Analysis. 3 Credit Hours.
Review of control concepts and application; state space representation of dynamical systems; controllability, observability; time invariant and time varying systems, design of full state feedback and output feedback systems; eigenstructure assignment; the linear quadratic regulator; Kalman filter; estimation and filtering; robust control via eigenstructure design, Kharitonov theorem, application examples.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ECE 5432. Game Theory and Applications in Engineering. 3 Credit Hours.
The course covers the basic framework for strategic games and its various manifestations. Topics include matrix games, extensive form games, mixed strategies, repeated games, Bayesian games, and cooperative games. The course continues with various applications of game theory in engineering systems. The course also covers applications of game theory as a design tool for engineering multi-agent systems, i.e., systems that are comprised of a collection of programmable decision-making components.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ECE 5512. Intro Digital Comm. 3 Credit Hours.
Baseband pulse, digital, and passband communications systems; properties and bandwidth of signals and noise; detection of signals in noise; signal-to-noise ratio (SNR); distortionless transmission and intersymbol interference; pulse code modulation; amplitude, phase and frequency modulation and demodulation; simulation of communication systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ECE 5514. Digital Signal Processing Analysis. 3 Credit Hours.
Topics covered are: various types of digital signal processing (DSP) techniques such as convolution, correlation, and filtering, as well as Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) all pass and comb digital filters, the Discrete Fourier Transform, and the use of MATLAB as a tool for DSP software tasks. A term project will be assigned.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.

ECE 5516. Introduction to Communication Networks. 3 Credit Hours.
Introduction to Internet and TCP and IP protocols, telephone networks, Local Area Networks, packet switching, ATM, and other related topics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Repeatability: This course may not be repeated for additional credits.
ECE 5526. Engineering Principles of Computer Intrusion and Detection. 3 Credit Hours.
This course provides an introduction of computer intrusion and detection techniques. It gives theoretical and practical foundations necessary to continue further learning of computer security. We will study and analyze critical security vulnerabilities of software design and network and information systems. The learned skills are widely used by IT security analysts in industries. At the end of the class the students will be able to understand basic concepts of intrusion detection and traffic analysis from a practical point of view. This course will provide the tools and knowledge necessary to continue further learning in computer security and advance further in the profession.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5516|Minimum Grade of B-|May not be taken concurrently.

ECE 5528. Introduction to Cryptography and Information Security. 3 Credit Hours.
This course covers the theory and practice of computer communications security. Topics include symmetric encryption, public and private key cryptography, message digests, digital signatures, secure email, and various types of authentication methods. We will review various cryptographic primitives, algorithms, intrusion attacks, and security protocols.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5528|Minimum Grade of B-|May not be taken concurrently.

ECE 5538. Hardware and Industrial Control System Security. 3 Credit Hours.
This course covers the theory and practice of hardware and control system security. Topics include digital system security, side channel attacks on cryptographic systems, industrial control system security, and intellectual property protection. We will review hardware implementation of cryptographic primitives, secure hardware design, and security protocols.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5528|Minimum Grade of B-|May not be taken concurrently.

ECE 5541. Hardware Security Lab. 3 Credit Hours.
This laboratory includes a university version of wired (with internet protocol suite of packets and layers) and wireless (with IEEE802.11 layers) equipment and physical network along with open source network security software. Depending on the application, the lab provides students flexibility to fully analyze protocols and security vulnerability with respect to the network, Programmable Logic Controller (PLC), and power grid, etc. Students gain hands-on experience from role-playing both as a black-hat hacker by instigating attacks and a white-hat hacker by performing digital forensics and penetration tests.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5548. Secure Computer Memory Architecture and Intrusion Prevention Methodologies. 3 Credit Hours.
This course covers physical computer memory organization and areas of vulnerability such as susceptibility to buffer overflow and Direct Memory Access (DMA) attacks. An overflow attack happens when the data written to a physical memory exceeds its allocated buffer size, which is in violation of memory safety rules. DMA happens when a data transfer is done via direct physical memory access, thus bypassing operating system's supervision. Such a "back door" access is intended to increase the hardware performance throughput but inadvertently creates a major hole in system security. This course analyzes physical memory design methodologies to prevent such intrusions.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5558. Reverse Engineering. 3 Credit Hours.
This course covers methodologies, equipment and software tools used to extract information and build knowledge from sophisticated modern-era hardware and software systems for reverse engineering purposes. Some systems require invasive and destructive technique to get to the source of the information, while for others, non-invasive monitoring and fault injection are sufficient methods. Reverse engineering equipment and tools include but are not limited to debuggers, disassemblers, logic analyzers, oscilloscopes, and simulators.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
ECE 5562. Wireless Communications Engineering. 3 Credit Hours.
This course provides a comprehensive introduction of physical-layer wireless communications, including: Cellular concepts; Wireless channel modeling; Modulation techniques; Multiple access techniques; Channel coding and wireless system capacity; Receiver diversity; Transmit diversity and multiple-input multiple-output (MIMO) technology; Equalization; Orthogonal frequency division multiplexing (OFDM); Wireless systems and standards, and latest developments in wireless technologies.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5568. Engineering Project Quality and Risk Management, and ISO Standards. 3 Credit Hours.
This course covers quality and risk management which are under the umbrella of project management, both go hand-in-hand to ensure best practices for engineering for products. Four components of quality management are quality planning, quality assurance, quality control and quality improvement. Also covered is ISO9001, quality management systems standards. Risk management includes enterprise risk management strategy, risk assessment, risk responses, risk communication and awareness training, and risk acceptance. Also covered is ISO 27001 and 2 on information security standards and best practices.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5572. Certificate Preparation - (ISC)2/CISPP-Information Systems Security. 3 Credit Hours.
The International Information Systems Security Certification Consortium (ISC)2 is a non-profit organization that specializes in information security certifications, which demonstrate certificate owners' competence in the subject manner. (ISC)2 is known as the "world's largest IT security organization" and among its certificates, Certified Information Systems Security Professional (CISSP) is the most widely valued. This course covers preparation for the CISSP-ISSEP certification, where ISSEP (Information System Security Engineering Professional) focuses on engineering aspects of the CISSP. The ISSEP exam focuses on four areas of information security: (1) Systems Security Engineering, (2) Certification and Accreditation (C&A) / Risk Management Framework (RMF), (3) Technical Management, and (4) United States Government Information Assurance Related Policies and Issuances.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5574. Certificate Preparation - Cisco Networking Academy. 3 Credit Hours.
This course covers various Cisco Certified Network Security topics concentrating on network security principals, tools, and configurations, and includes a hands-on lab equipped with Cisco networking equipment.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5575. Capstone Project. 3 Credit Hours.
A Capstone Project is a work-study project where a student with support from his/her sponsoring entity works on a current or emerging challenge on cybersecurity. Engineering Resilient Systems (ERS) is an example of a DoD sponsored Capstone Project. Through Capstone Project, a student will develop tools and procedures to produce a complete and robust product requirement, make efficient and effective engineering decisions, consider manufacturability of a system design, and establish a baseline resiliency including Tactics, Techniques, and Procedures (TTP) against threats.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5612. Advanced Processor Systems. 3 Credit Hours.
Hardware description language (Verilog) design of processor systems for digital signal processing and data communication. Projects will be assigned in simulation and synthesis of dataflow and processor architectures targeting field programmable gate arrays (FPGA).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
ECE 5622. Introduction to Computer Architecture. 3 Credit Hours.
Instruction set architectures, Register Transfer Level hardware description. Data-path design. Controller design. Caches and memory systems. Addressing. Microprogramming. Computer arithmetic. Survey of current computers and microprocessors. Projects will include Verilog/VHDL implementation of data-path components and testing them on FPGAs.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5712. Power Systems Engineering. 3 Credit Hours.
This course introduces the modern power systems and its changing landscape. The course covers the basics of power generation and transformers, and an introduction to power electronic devices, AC transmission and distribution, power flow, economic dispatch, transient and stability analysis, short circuit analysis, and HVDC systems, power system protection, power market deregulation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5714. Introduction to Intelligent Systems Engineering. 3 Credit Hours.
Introduction of the use of artificial intelligence techniques to develop intelligent systems. The course gives the student 1) an overview of what artificial intelligence is and its current state; 2) an overview of intelligent systems --what they are and their possible future role in society; 3) a practical and theoretical knowledge of expert systems, their development, implementation and maintenance and 4) an introduction to intelligent tutoring systems and to provide a perspective about the potential impact of these systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5722. Power Electronic Devices and Systems. 3 Credit Hours.
This course introduces power electronic devices and circuits, and their applications in modern power systems. Topics include DC-DC converters in buck and boost topologies, and their modeling and feedback control; AC-DC rectification and control; DC-AC inverters, modeling, and voltage and frequency control; Three-phase inverters, and HVDC transmission. This course will use Matlab/Simulink simulation for student projects and homeworks.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5732. Electric Machines and Drives. 3 Credit Hours.
Fundamentals of electromechanical energy conversion, electric drives and systems. Transformers, DC machines, synchronous machines, induction motors, dq-transformation, vector control of induction motors, reluctance motors, single phase motors, brushless dc motor. Introduction to power electronics and their applications in power drives.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 5999. Research Experience in Electrical Engineering. 0 Credit Hours.
Research Experience provides graduate students laboratory experiences/research practices prior to undertaking independent, directed, master project, master's thesis, or dissertation research. This course allows graduate students the opportunity to learn the use of laboratory equipment, designing and carrying out an experiment(s), collecting preliminary data, field experiences, and participation in laboratory meeting, etc. with faculty which may lead to identifying a faculty mentor. The course will be graded Pass (P) or Fail (F). The Research Experience is a non-repeatable course. After the completion of ECE 5999 - Research Experience in ECE, students will need to be enrolled in independent study, directed research, master's research, master's thesis, dissertation proposal, or dissertation if they continue in an active research program.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 8110. Special Topics in Electrical and Computer Engineering. 3 Credit Hours.
Selected advanced topics in various major research areas under electrical and computer engineering.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
ECE 8324. Mixed Signal VLSI Design. 3 Credit Hours.
Basic MOS device physics, single state amplifiers, frequency response, op amps, switched capacitor circuits, short-channel effects, amplifier design for wireless communication, low power static RAM architectures, layout and packaging.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5324|Minimum Grade of C|May not be taken concurrently.

ECE 8334. Nano Applications, MEMS & NEMS. 3 Credit Hours.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5324|Minimum Grade of C|May not be taken concurrently.

ECE 8412. Optimal and Robust Control. 3 Credit Hours.
Concept of optimality, calculus of variations, Euler-Lagrange equation, Pontryagin's minimum principle, Bellman's equation, Kalman filter, uncertainties in physical systems; structured and unstructured uncertainties; application of the Lyapunov method to robust control problems; robust optimal control; state space design for finite and infinite horizon problems; H-infinity design.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5412|Minimum Grade of C|May not be taken concurrently.

ECE 8414. Adaptive Control. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5412|Minimum Grade of C|May not be taken concurrently.

ECE 8512. Signal Processing and Communication Theory. 3 Credit Hours.
Coherent and non-coherent detection of binary and M-ary signals in noise; waveform coding, linear block coding; convolutional, cyclic and turbo codes; error probability and bandwidth-efficiency plane in the design of digital communications systems; multipath and fading channels; simulation of communication systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ECE 5512|Minimum Grade of C|May not be taken concurrently
AND ENGR 5033|Minimum Grade of C|May not be taken concurrently)

ECE 8514. Applications in Digital Signal Processing. 3 Credit Hours.
FIR and IIR digital filter design, finite word length effects, filter banks, multirate signal processing, spectral analysis (classical, modern, parametric and nonparametric techniques), adaptive filtering (Wiener filter theory) and speech production, analysis, and processing tools and speech coding. Computer experiments using MATLAB will be an integral part of the course.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5033|Minimum Grade of C|May not be taken concurrently.
ECE 8516. Design and Performance of Communication Networks. 3 Credit Hours.
An overview of the technologies, architectures and protocols used to build high-speed communication networks. Design and performance analysis techniques for computer communication networks. Topics will include: design and performance analysis of wired and wireless local networks, sensor networks, and Internet. Projects will include developing stochastic models, queueing analysis, and simulations.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 8524. Speech Signal Processing. 3 Credit Hours.
Spectral analysis of non-stationary signals, short-time Fourier transform, homomorphic filtering and filter bank, Speech compression, and synthesis techniques. Weiner filtering for speech enhancement.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 8514|Minimum Grade of C|May not be taken concurrently.

ECE 8525. Fundamentals of Speech Recognition. 3 Credit Hours.
This course introduces students to the theory and implementation of modern day speech recognition systems. We begin with a review of pattern recognition and machine learning, including topics such as Gaussian mixture models and Bayesian models. We then discuss the three main components of a speech recognition system: feature extraction, acoustic modeling and language modeling. We conclude the course with an overview of state of the art systems. Students will learn how to simulate and evaluate complex machine learning algorithms such as hidden Markov models and neural networks. Data-driven methodologies will be emphasized.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ENGR 5022|Minimum Grade of B-|May not be taken concurrently)
AND (ENGR 5033|Minimum Grade of B-|May not be taken concurrently)

ECE 8526. Information Theory. 3 Credit Hours.
Information Theory is a field that has been central to the development of modern communications and computing technologies. The goal of this course is to provide the student with a thorough understanding of the concepts of entropy and information, and how to apply these to real world problems such as speech recognition, language engineering, signal compression, and financial modeling. A secondary goal is to develop a mathematically rigorous understanding of methods for measuring and manipulating various measures of information in signals and systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ENGR 5022|Minimum Grade of B-|May not be taken concurrently)
AND (ENGR 5033|Minimum Grade of B-|May not be taken concurrently)

ECE 8527. Introduction to Machine Learning and Pattern Recognition. 3 Credit Hours.
Pattern recognition theory and practice is concerned with the design, analysis, and development of methods for the classification or description of patterns, objects, signals, and processes. At the heart of this discipline is our ability to infer the statistical behavior of data from limited data sets, and to assign data to classes based on generalized notions of distances in a probabilistic space. Many commercial applications of pattern recognition exist today, including voice recognition, fingerprint classification, and retinal scanners. Recent developments in statistical modeling using Bayesian techniques, neural networks, decision trees, fuzzy logic, and syntactic structures have accelerated the growth of pattern recognition applications. The objective of this course is to introduce fundamental methods of pattern recognition, both statistical and neural, with examples from several application areas.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ENGR 5022|Minimum Grade of B-|May not be taken concurrently)
AND (ENGR 5033|Minimum Grade of B-|May not be taken concurrently)
ECE 8528. Advanced Topics in Statistical Modeling for Engineering Applications. 3 Credit Hours.
This course builds on a basic knowledge of machine learning and reviews recent advances in the field. It is a research-oriented course intended to complement a student's thesis or dissertation research. The course will focus on a selection of emerging machine learning algorithms and analyze contemporary publications on these techniques. The emphasis will be on algorithms suited to large, complex data sets. Both supervised and unsupervised learning methodologies will be discussed. Applications will be drawn from several signal processing disciplines including speech, image and bioengineering applications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ENGR 5022|Minimum Grade of B-|May not be taken concurrently)
AND (ENGR 5033|Minimum Grade of B-|May not be taken concurrently)
AND (ECE 8527|Minimum Grade of B-|May not be taken concurrently)

ECE 8529. Fundamentals of EEG Processing. 3 Credit Hours.
Electroencephalography (EEG) records electrical activity along the scalp, measuring spontaneous electrical activity of the brain. The signals measured along the scalp can be correlated with brain activity, which makes it a primary tool for diagnosis of brain-related illnesses. EEG specialists review these waveforms and develop a diagnosis. EEGs traditionally have been used to diagnose epilepsy and strokes. Other common clinical uses have been for diagnoses of coma, encephalopathies, brain death and sleep disorders. EEGs are increasingly being used to diagnose head-related trauma injuries and Alzheimer's disease. Hence, there is a growing need for expertise to interpret EEGs and, equally important, to understand how these conditions manifest themselves in the EEG signal. In this course we will discuss the techniques neurologists use to manually interpret EEGs. A vast archive of clinical EEG recordings will be studied. Since EEG signals are very low-level electrical signals, we will then discuss digital signal processing that is used to convert the raw electrical signals into visualizations that can be readily interpreted. We will also introduce machine learning techniques that are used to automatically interpret and transcribe these signals.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ECE 8622. Advanced Computer Architecture. 3 Credit Hours.
Advanced course in the design and analysis of computer architecture. Topics will include instruction level parallelism, digital signal processors, network processors and multi-microprocessors. Projects will focus on the design, design analysis and FPGA implementations of computing systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 5322|Minimum Grade of C|May not be taken concurrently.

ECE 9182. Independent Study I. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by MS/MSE students and once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
ECE 9324. VLSI Physical Design. 3 Credit Hours.
This course provides a comprehensive background in the principles and algorithms of VLSI physical design. The algorithms are presented in an intuitive manner so that the student can concentrate on the basic idea of the algorithms. The students are provided enough details to implement the algorithms.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ECE 8324|Minimum Grade of C|May not be taken concurrently)
AND (ECE 5324|Minimum Grade of C|May not be taken concurrently)

ECE 9412. Nonlinear Control System. 3 Credit Hours.
Modeling of nonlinear systems, types of nonlinearity; Phase Plane Analysis, construction of phase portrait, limit cycle, saddle point; Existence and uniqueness of solutions, sensitivity; Lyapunov Stability, region of attraction, construction of Lyapunov functions; Perturbation Analysis variation of parameters, Method of averaging, Describing Functions, frequency domain analysis; Sliding Mode Control, sliding surface; Feedback Linearization, Lie algebra, state and output linearization, applications.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 8412|Minimum Grade of C|May not be taken concurrently.

ECE 9512. Detection, Estimation, and Modulation Theory. 3 Credit Hours.
Signal detection and estimation in white and non-white noise, MAP estimation, applications in data and telecommunications. Wiener and Kalman-Bucy filters, linear and non-linear modulation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ENGR 5033|Minimum Grade of C|May not be taken concurrently.

ECE 9514. Adaptive Signal Processing. 3 Credit Hours.
Adaptive filter techniques such as Weiner filter, Linear Prediction, Least-Mean-Square, Recursive Least-Squares, Kalman Filtering algorithms. Introduction to the application of adaptive filters to communications, control, and speech processing.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
(ECE 5514|Minimum Grade of C|May not be taken concurrently
AND ECE 8514|Minimum Grade of C|May not be taken concurrently)

ECE 9524. Digital Image Processing. 3 Credit Hours.
P2D digital filters, digital image edge detection and segmentation, feature extraction, deblurring, wavelet transforms, JPEG image compression, Fourier optics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 8514|Minimum Grade of C|May not be taken concurrently.
ECE 9622. Parallel Processing Architectures. 3 Credit Hours.
This course provides an in-depth study of the design, engineering, and evaluation of modern parallel computers. Design issues covered include: naming, replication, synchronization, latency, overhead, and bandwidth. Other topics include scalable multiprocessors and interconnection network design.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

Pre-requisites:
ECE 8612|Minimum Grade of C|May not be taken concurrently.

ECE 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, students will select a topic in electro-technology to be researched using at least five references. An extensive research paper must be submitted which will be reviewed by two faculty members. The project report must also be presented at an open seminar. Projects related to industrial applications are encouraged. For non-thesis students only.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have completed their coursework but who have not yet passed both the Ph.D. Preliminary Examination.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9995. Project. 1 to 3 Credit Hour.
Under the guidance of a faculty member, students will select a topic in electro-technology to be researched using at least five references. Student present the research at an open seminar, and submits an extensive research paper, which will be reviewed by two faculty members. Projects related to industrial applications are encouraged. For non-thesis students only.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9996. Thesis. 1 to 3 Credit Hour.
Under the guidance of a faculty member, students will select a topic in electro-technology, and conduct research leading to submission and oral presentation of a thesis proposal and the final defense of the thesis. For thesis students only.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9998. Pre-Dissertation Research. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have passed both the Preliminary and Qualifying Examinations but who have not been elevated to candidacy.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

ECE 9999. Dissertation Research. 1 to 6 Credit Hour.
This course is intended only for those students who have achieved Ph.D. Candidacy status. A minimum of 6 semester hours is required for graduation.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.
Student Attribute Restrictions: Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

Repeatability: This course may be repeated for additional credit.
Engineering Courses

ENGR 5011. Engineering Mathematics I. 3 Credit Hours.
This is a survey course in essential mathematics for first-year graduate students in engineering and physical sciences. Topics include analytic methods in ordinary differential equations, complex-variable theory, the laplace transform and its inversion, and initial-value problems and boundary-value problems. Matlab, numerical methods, and introductory numerical algorithm design are introduced.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5012. Engineering Mathematics II. 3 Credit Hours.
This is a survey course in classical numerical and analytical methods for partial differential equations, for first-year masters and doctoral students in engineering and physical sciences. Topics include analytic methods and numerical methods for partial differential equations in cartesian and non-cartesian coordinate systems, and an introduction to perturbation theory. The course will emphasize quantitative analysis, and assignments will entail computational algorithm design.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5022. Engineering Analysis and Applications. 3 Credit Hours.
Vector space, basis, projection, null space, function space, L2 and space of continuous functions, Hilbert space, orthogonality, generalized Fourier series, linear transformation, adjoint transformation, eigenvalue problem, linear functional, Gateaux and Frechet differential, constrained optimization, infinite dimensional systems, complex analysis.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5031. Engr Prob Stats Stoc Met. 3 Credit Hours.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5032. Probability, Statistics, and Stochastic Methods. 3 Credit Hours.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5033. Probability and Random Processes. 3 Credit Hours.
Sets and events, Random variables, Distribution and density functions, Functions of multiple random variables, Moments and conditional statistics, Information entropy, stochastic processes, wide-sense stationary process, ergodicity, correlation, and power spectrum of stationary processes. Applications to sampling theory and signal modulation and detection.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5110. Special Topics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
ENGR 5116. Spacecraft Systems Engineering. 3 Credit Hours.
The concept of systems engineering is introduced using a satellite application. Systems engineering is a top-down approach to the design, implementation, testing, and deployment of large-scale systems to meet the needs of users. The topics will include systems engineering methodology, dynamics of spacecraft, and celestial mechanics. This course will also introduce the notion of invention and innovation, and how they are related to the intellectual property issues.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5117. Experimental Methods. 3 Credit Hours.
Application and design of experimental techniques and measurement systems used in engineering laboratories. Introduction to the DMM, digital scope, and computer-based data acquisition systems for measurements of force, motion, pressure, temperature, and flow in steady and unsteady systems. Data transmission, data analysis and presentation, and computer interfacing techniques. Statistical methods and uncertainty analysis. Hands-on experience with state-of-the-art instrumentation systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5311. Deformation and Fracture of Engineering Materials. 3 Credit Hours.
Elastic and plastic deformation of materials; introduction to dislocation theory; failure analysis. Topics include loading in real-life situations, variable loading, failure theories, buckling and instability, fatigue analysis, and fracture mechanics. Case histories are introduced from a variety of industries including automotive, aerospace, utilities, oil and gas, petrochemical and biomedical. Helpful techniques are introduced such as operating stress maps.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5314. Continuum Mechanics. 3 Credit Hours.
This course covers tensors, kinematics of a continuum, stress, integral formulations, linear isotropic elastic solid, and an introduction to Newtonian Fluid (CLO 3).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5334. Dynamical Systems. 3 Credit Hours.
This course focuses on the algebraic and differential equations governing the static and dynamic 3D motion of 3D bodies, including vectors, vector differentiation, and dyads. The equations of motion for multibody systems will be derived using Newton-Euler, Lagrange, and Kane's methods. Computational tools for 3D force and motion analysis will be used to simulate physical systems.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5511. Fluid Dynamics. 3 Credit Hours.
Navier-Stoke's equation, Laminar and turbulent flow, boundary layer phenomena, compressible fluid flow including isotropic flow, shock waves, friction flow, and flow with heat transfer.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 5576. Computational Fluid Dynamics. 3 Credit Hours.
This course provides an introduction to numerical methods for solution of initial and boundary value problems with special emphasis on finite element and finite difference discretization methods. Students learn to implement the algorithm by using MATLAB programming to solve problems in heat transfer and fluid flow.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

ENGR 8110. Special Topics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
ENGR 9182. Independent Study I. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by MS/MSE students and once by Ph.D. students.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9185. Exper Engineer Prof I. 1 to 3 Credit Hour.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9285. Exper Engineer Prof II. 1 to 3 Credit Hour.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9990. Engineering Seminar. 1 to 3 Credit Hour.
Students present their research results at an open seminar. The seminars may be arranged on a biweekly basis over the semester. Active participation of all graduate students is expected.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, the student will conduct independent research on a selected topic in engineering.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have completed their coursework but who have not yet passed both the Ph.D. Preliminary Examination.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9995. Project. 1 to 3 Credit Hour.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9996. Thesis. 3 Credit Hours.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

ENGR 9998. Pre-Dissertation Research. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have passed both the Preliminary and Qualifying Examinations but who have not been elevated to candidacy.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.
ENGR 9999. Dissertation Research. 1 to 6 Credit Hour.
This course is intended only for those students who have achieved Ph.D. Candidacy status. A minimum of 6 semester hours is required for graduation.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Student Attribute Restrictions:** Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

**Repeatability:** This course may be repeated for additional credit.

### Mechanical Engineering Courses

**MEE 5110. Special Topics. 3 Credit Hours.**
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

**MEE 5117. Finite Element Analysis. 3 Credit Hours.**
Concepts and techniques of finite element and finite difference methods; mesh generation techniques; computer graphics presentation methods. Application to solids, liquids, and gases in the areas of stress, strain, deflection elasticity, heat transfer, fluid flow, and combustion.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**MEE 5201. Thermodynamics of Materials. 3 Credit Hours.**
An introductory master's level course that explores materials from a thermodynamic perspective: Includes the laws of thermodynamics, free energy, chemical potential, stability, etc. A detailed analysis of phase diagrams is presented in the second half of the course.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**MEE 5203. Advanced Materials Science. 3 Credit Hours.**
Chemical bonding, crystallography, defects and their effects on material properties, nucleation, growth, and microstructure development.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**MEE 5204. Solid State Physics for Material Science. 3 Credit Hours.**
Crystal structures, bonding, crystal binding energies, reciprocal lattice, elastic properties, phonons, thermal properties, electronic properties, energy bands, band structures, semiconductors, doping, carrier concentration, fermi surfaces, metals, excitation, optical properties, electron scattering, carrier transport, impurities, defects, surfaces, interfaces.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**MEE 5205. Microscopy and Microanalysis of Materials. 3 Credit Hours.**
This course will cover various Microscopy and Microanalysis techniques which are widely used in research labs and in industries to characterize micro and nano structure and chemical composition of solid matter. Among them are visual light, scanning probe and electron beam microscopy and associated spectroscopy. The primary focus will be on fundamental aspects and experimental methods of Scanning Electron Microscopy (SEM) and associated spectroscopy. The SEM facility will be used for individual student projects. Particular attention will be given to the selection criteria used for choosing the appropriate technique for materials characterization.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.

**MEE 5312. Mechanics of Composite Materials. 3 Credit Hours.**
Introduction to the behavior of composite materials and their use in engineering structures: behavior and properties of the constituent fibers and matrices, micromechanical predictions of composite properties, anisotropic elasticity, behavior of composite laminae, classical lamination theory; fracture mechanisms, failure theories; behavior of composite plates and beams.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may not be repeated for additional credits.
MEE 5411. Introduction to Mobile Robotics. 3 Credit Hours.
How can one create mobile robots that operate autonomously in cluttered indoor and outdoor environments? How do robots determine their state and properties from noisy sensor data to accomplish navigation and manipulation tasks? The Introduction to Mobile Robotics course will address motion planning, control, sensing and estimation for mobile robots. The goal of the class is to train students to develop real-time planning and control software modules for robotic systems. Students taking this course are expected to be familiar with differential equations, linear algebra, and multi-variable calculus. Experience with programming in Matlab or Octave is recommended (and Matlab will be used in the course).

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5511. Thermodynamic Properties. 3 Credit Hours.
Review of quantum mechanics and introduction to statistical mechanics. Statistical thermodynamics and various models of matter. Accuracy and trends of the predicted properties of various materials.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5512. Compressible Fluid Dynamics. 3 Credit Hours.
This course introduces students to the subject of high speed gas dynamics. Compressible flows exhibit fundamentally different behavior from those in low speed, constant density fluids. Such flows are found in aerodynamics, combustors, turbines, jets, gas pipelines, and wind tunnel facilities. Students study phenomena associated with supersonic flows, including normal and oblique shocks, expansion fans, and compressible flows with friction and/or heat transfer. An introduction to high temperature and rarified gas dynamics is also included.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5575. Renewable and Alternative Energy. 3 Credit Hours.
The objective of the course is to establish the theoretical basis for the description of regular and chaotic dynamic systems. Students learn to understand the basic ideas of dynamic systems and the nature of chaotic behavior so they can apply these ideas to particular systems. They also learn how to choose the appropriate modeling techniques and hypothesis to establish a mathematical model of a qualitatively described phenomenon. Discussed applications include examples from fluid mechanics, physics, and biology.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5576. Photovoltaic Syst Design. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5577. Power Generation and Storage Technologies. 3 Credit Hours.
This course will give an overview of electric power generation technologies including coal, gas, and nuclear power plants, as well as some emerging technologies such as photovoltaic. This course will also discuss technologies used in power transmission and distribution such as overhead power line conductors. Power storage technologies will also be introduced including compressed air, flywheel, hydrogen, and batteries.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5731. Cardiovascular Fluid Dynamics. 3 Credit Hours.
Mechanics of blood circulation, fluid mechanics of the heart, blood flow in arteries, unsteady flow in veins, current concepts in circulatory assist devices, biofluidics, and other selected topics.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.
MEE 5732. Tissue Biomechanics. 3 Credit Hours.
Tissue Biomechanics course is an introductory course about the mechanical properties of living tissues. The emphasis of the course is on the meaning of constitutive models for bio-solids and bio-fluids. Topics include a review of elastic, viscous, and viscoelastic constitutive models; bioviscoelastic solids; mechanical properties of blood vessels; mechanics of skeletal and heart muscles.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5733. Viscoelasticity. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 5734. Forensic Engineering. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 8110. Special Topics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

MEE 8315. Fracture Mechanics. 3 Credit Hours.
Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may not be repeated for additional credits.

MEE 9182. Independent Study I. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by MS/MSE students and once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

MEE 9282. Independent Study II. 3 Credit Hours.
Special study in a particular aspect of engineering under the direct supervision of a graduate faculty member. May be taken once by Ph.D. students.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

MEE 9991. Directed Research. 1 to 6 Credit Hour.
Under the guidance of a faculty member, the student will conduct independent research on a selected topic in engineering.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

MEE 9994. Preliminary Examination Preparation. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have completed their coursework but who have not yet passed both the Ph.D. Preliminary Examination.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.

MEE 9995. Project. 1 to 3 Credit Hour.
A project assigned with the approval of the Mechanical Engineering Graduate Committee and conducted under the supervision of a graduate faculty advisor. An oral presentation in an open seminar and a written report are required to complete the independent project. Projects related to industrial applications are encouraged. For non-thesis students only.

Level Registration Restrictions: Must be enrolled in one of the following Levels: Graduate.

Repeatability: This course may be repeated for additional credit.
MEE 9996. Thesis. 1 to 3 Credit Hour.
Master's thesis. May be taken twice.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

MEE 9998. Pre-Dissertation Research. 1 to 6 Credit Hour.
This course is intended for Ph.D. students who have passed both the Preliminary and Qualifying Examinations but who have not been elevated to candidacy.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.

**Repeatability:** This course may be repeated for additional credit.

MEE 9999. Dissertation Research. 1 to 6 Credit Hour.
This course is intended only for those students who have achieved Ph.D. Candidacy status. A minimum of 6 semester hours is required for graduation.

**Level Registration Restrictions:** Must be enrolled in one of the following Levels: Graduate.
**Student Attribute Restrictions:** Must be enrolled in one of the following Student Attributes: Dissertation Writing Student.

**Repeatability:** This course may be repeated for additional credit.