Electrical Engineering & Computer Science

2015-2016

Degrees Offered

- Master of Science (Computer Science)
- Master of Science (Electrical Engineering)
- Doctor of Philosophy (Computer Science)
- Doctor of Philosophy (Electrical Engineering)

Program Overview

The Electrical Engineering and Computer Science Department (EECS) offers the degrees Master of Science and Doctor of Philosophy in Computer Science and the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. These degree programs demand academic rigor and depth yet also address real-world problems.

The Department also supports graduate degrees in Mathematical and Computer Sciences (computer science option) and Engineering (electrical specialty), but these degrees have been retired. For details on these programs, please see the 2011-2012 CSM Graduate Bulletin. Students admitted to the Mathematical and Computer Sciences (computer science option) or Engineering (electrical specialty) graduate programs for the 2012-2013 academic year may opt to change their program of study to EE or CS as appropriate with their background and complete the degree requirements for the selected degree.

The EECS department has nine areas of research activity that stem from the core fields of Electrical Engineering and Computer Science: (1) Antennas and Wireless Communications, (2) Applied Algorithms and Data Structures, (3) Education (4) Energy Systems and Power Electronics, (5) High Performance Computing, (6) Human-Centered Robotics, (7) Information and Systems Sciences, (8) Machine Learning, and (9) Networking. Additionally, students may study areas such as Embedded Systems and/or Robotics, which include elements from both Computer Science and Electrical Engineering disciplines. In many cases, individual research projects encompass more than one research area.

Antennas and Wireless Communications research areas include electromagnetics, antennas, microwave, and wireless communications. Applications address current academic, industry, and society needs. Examples include the design of antennas, antenna arrays, and microwave RF devices for communication and sensing applications.

Applied Algorithms and Data Structures is an interdisciplinary research area that is applied to areas such as VLSI design automation, cheminformatics, computational materials, and cyber-physical systems.

Education research includes areas within STEM education and K-12 education.

Energy Systems and Power Electronics is focused on both fundamental and applied research in the interrelated fields of conventional electric power systems and electric machinery, renewable energy and distributed generation, energy economics and policy issues, power quality, power electronics and drives. The overall scope of research encompasses a broad spectrum of electrical energy applications including investor-owned utilities, rural electric associations, manufacturing facilities, regulatory agencies, and consulting engineering firms.

High Performance Computing research is focused on compiler-based code and data transformation, memory optimization for both multi-core and many-core processors, speculative parallelization, approximate computation and GPU-based acceleration of Big Data applications (such as graph processing and machine learning algorithms).

Human-Centered Robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making.

Information and Systems Sciences is an interdisciplinary research area that encompasses the fields of control systems, communications, signal and image processing, compressive sensing, robotics, and mechatronics. Focus areas include intelligent and learning control systems, fault detection and system identification, computer vision and pattern recognition, sensor development, mobile manipulation and autonomous systems. Applications can be found in renewable energy and power systems, materials processing, sensor and control networks, bio-engineering, intelligent structures, and geosystems.

Machine Learning includes research in developing mathematical foundations and algorithm design needed for computers to learn. Focus areas include fundamental research in machine learning and numerical methods, as well as developing novel algorithms for bioinformatics, data mining, computer vision, biomedical image analysis, parallel computing, natural language processing, and data privacy.

Networking research includes mobile networks, sensor networks, pervasive computing, and wireless networking. Focus areas include credible network simulation, cyber-physical systems, game theoretic algorithm design, middleware, and mobile social applications. Interdisciplinary research also exists, mainly in the use of wireless sensor networks for environmental monitoring and development of energy efficient buildings.

Program Details

The EECS Department offers the degrees Master of Science and Doctor of Philosophy in Computer Science and the degrees Master of Science and Doctor of Philosophy in Electrical Engineering. The master's program is designed to prepare candidates for careers in industry or government or for further study at the Ph.D. level; both thesis and non-thesis options are available. The Ph.D. degree program is sufficiently flexible to prepare candidates for careers in industry, government, or academia. See the information that follows for full details on these four degrees.

Combined Program: The EECS Department also offers combined BS/MS degree programs. These programs offer an expedited graduate school application process and allow students to begin graduate coursework while still finishing their undergraduate degree requirements. This program is described in the undergraduate catalog and is in place for both Computer Science and Electrical Engineering students. The Physics combined program also offers a track in Electrical Engineering. Details on this program can be found in the CSM Undergraduate Bulletin, and course schedules for this program can be obtained in the Physics Department.
Prerequisites

Requirements for Admission to CS: The minimum requirements for admission to the M.S. and Ph.D degrees in Computer Science are:

- Applicants must have a Bachelor's degree, or equivalent, from an accredited institution with a grade-point average of 3.0 or better on a 4.0 scale.
- Students are expected to have completed two semesters of calculus, along with courses in object-oriented programming and data structures, and upper level courses in at least three of the following areas: software engineering, numerical analysis, computer architecture, principles of programming languages, analysis of algorithms, and operating systems.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Requirements for Admission to EE: The minimum requirements for admission to the M.S. and Ph.D. degrees in Electrical Engineering are:

- A baccalaureate degree in engineering, computer science, a physical science, or math with a grade-point average of 3.0 or better on a 4.0 scale.
- Graduate Record Examination (Quantitative section) score of 151 or higher (or 650 on the old scale). Applicants who have graduated with an engineering degree from CSM within the past five years are not required to submit GRE scores.
- TOEFL score of 79 or higher (or 550 for the paper-based test or 213 for the computer-based test) for applicants whose native language is not English. In lieu of a TOEFL score, and IELTS score of 6.5 or higher will be accepted.
- For the Ph.D. program, prior research experience is desired but not required.

Admitted Students: The EECS Department Graduate Committee may require that an admitted student take undergraduate remedial coursework to overcome technical deficiencies. The committee will decide whether to recommend regular or provisional admission.

Transfer Courses: Graduate level courses taken at other universities for which a grade equivalent to a "B" or better was received will be considered for transfer credit with approval of the Advisor and/or Thesis Committee, and EECS Department Head, as appropriate. Transfer credits must not have been used as credit toward a Bachelor degree. For the M.S. degree, no more than nine credits may transfer. For the Ph.D. degree, up to 24 credit hours may be transferred. In lieu of transfer credit for individual courses, students who enter the Ph.D. program with a thesis-based master's degree from another institution may transfer up to 36 hours in recognition of the course work and research completed for that degree.

400-level Courses: As stipulated by the CSM Graduate School, students may apply toward graduate degree requirements a maximum of nine (9.0) semester hours of department-approved 400-level course work.

Advisor and Thesis Committee: Students must have an Advisor from the EECS faculty to direct and monitor their academic plan, research, and independent studies. Advisors must be full-time permanent members of the faculty. In this context, full-time permanent members of the faculty are those that hold the rank of professor, associate professor, assistant professor, research professor, associate research professor or assistant research professor. Upon approval by the Graduate Dean, adjunct faculty, teaching faculty, visiting professors, emeritus professors and off-campus representatives may be designated additional co-advisors. A list of EECS faculty by rank is available in the faculty section (p. ) of the bulletin.

Master of Science (thesis option) students in both EE and CS must have at least three members on their Thesis Committee; the Advisor and one other member must be permanent faculty in the EECS Department. Both EE and CS Ph.D. Thesis Committees must have at least four members; the Advisor/co-advisor and two additional members must be permanent faculty in the EECS Department, and one member must be outside the departmental faculty and serving as chair of the committee. Students who choose to have a minor program must select a representative from the minor area of study to serve on the Thesis Committee.

Degree Audit and Admission to Candidacy: Master students must complete the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline. Ph.D. students need to submit the Degree Audit form (http://gradschool.mines.edu/Degree-Audit) by the posted deadline and need to submit the Admission to Candidacy form (https://inside.mines.edu/GS-Candidacy-Addendum) two weeks prior to census day of the semester in which they want to be considered eligible for reduced registration.

Time Limit: As stipulated by the CSM Graduate School, a candidate for a Masters degree must complete all requirements for the degree within five years of the date of admission into the degree program. A candidate for a doctoral degree must complete all requirements for the degree within nine years of the date of admission into the degree program.

Program Requirements

Master of Science - Computer Science

The M.S. degree in Computer Science (Thesis or Non-Thesis option) requires 36 credit hours. Requirements for the thesis M.S. are 24 hours of coursework plus 12 hours of thesis credit leading to an acceptable Master's thesis; thesis students are encouraged to find a thesis advisor and form a Thesis Committee by the end of the first year. The non-thesis option consists of two tracks: a Project Track and a Coursework Track.

Requirements for the Project Track are 30 hours of coursework plus 6 hours of project credit; requirements for the Coursework Track are 36 hours of coursework. The following four core courses are required of all students. Students may choose elective courses from any CSCI graduate course offered by the Department. In addition, up to six credits of elective courses may be taken outside of CSCI. Lastly, a maximum of six Independent Study course units can be used to fulfill degree requirements.

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<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Units</th>
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<tbody>
<tr>
<td>CSCI406</td>
<td>ALGORITHMS</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI442</td>
<td>OPERATING SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI561</td>
<td>THEORY OF COMPUTATION</td>
<td>3.0</td>
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</table>
M.S. Project Track: Students are required to take six credits of CSCI700 to fulfill the MS project requirement. (It is recommended that the six credits consist of two consecutive semesters of three credits each.) At most six credits of CSCI700 will be counted toward the Masters non-thesis degree. Deliverables include a report and a presentation to a committee of two CS faculty including the Advisor. Deliverables must be successfully completed in the last semester in which the student registers for CSCI700. A student must receive two “pass” votes (i.e., a unanimous vote) to satisfy the project option.

M.S. Thesis Defense: At the conclusion of the M.S. (Thesis Option), the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn an M.S. degree.

Doctor of Philosophy - Computer Science
The Ph.D. degree in Computer Science requires 72 credit hours of course work and research credits. Required course work provides a strong background in computer science. A course of study leading to the Ph.D. degree can be designed either for the student who has completed the master's degree or for the student who has completed the bachelor's degree. The following five courses are required of all students. Students who have taken equivalent courses at another institution may satisfy these requirements by transfer.

<table>
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<tr>
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<td>3.0</td>
</tr>
<tr>
<td>CSCI561</td>
<td>THEORY OF COMPUTATION</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI564</td>
<td>ADVANCED COMPUTER ARCHITECTURE</td>
<td>3.0</td>
</tr>
<tr>
<td>SYGN502</td>
<td>INTRODUCTION TO RESEARCH ETHICS</td>
<td>1.0</td>
</tr>
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Ph.D. Qualifying Examination: Students desiring to take the Ph.D. Qualifying Exam must have:

- (if required by your advisor) taken SYGN 501 The Art of Science (previously or concurrently),
- taken at least four CSCI 500-level courses at CSM (only one CSCI599 is allowed), and
- maintained a GPA of 3.5 or higher in all CSCI 500-level courses taken.

The Ph.D. Qualifying Exam is offered once a semester. Each Ph.D. Qualifying Exam comprises of two research areas, chosen by the student. The exam consists of the following steps:

Step 1. A student indicates intention to take the CS Ph.D. Qualifying Exam by choosing two research interest areas from the following list: algorithms, education, high-performance computing, human-centered robotics, image processing, machine learning, and networks. This list is subject to change, depending on the current faculty research profile. Students must inform the EECS Graduate Committee Chair of their intention to take the exam no later than the first class day of the semester.

Step 2. The Graduate Committee Chair creates an exam committee of (at least) four appropriate faculty. The exam committee assigns the student deliverables for both research areas chosen. The deliverables will be some combination from the following list:

- complete a hands-on activity (e.g., develop research software) and write a report;
- complete a set of take-home problems;
- write a literature survey (i.e., track down references, separate relevant from irrelevant papers); and
- read a set of papers on research skills (e.g., ethics, reviewing) and answer questions.

Step 3. The student must complete all deliverables no later than the Monday of Dead Week.

Step 4. Each member of the exam committee makes a recommendation on the deliverables from the following list: strongly support, support, and do not support. To pass the Ph.D. Qualifying Exam, the student must have at least two “strongly supports” and no more than one “do not support”. The student is informed of the decision no later than the Monday after finals week. A student can only fail the exam one time. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student’s Thesis Committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time Ph.D. students must complete the following requirements within two calendar years of enrolling in the Ph.D. program:

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student’s Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research. A student must “pass” this defense to earn a Ph.D. degree.

Master of Science – Electrical Engineering
The M.S. degree in Electrical Engineering (Thesis or Non-Thesis Option) requires 30 credit hours. Requirements for the thesis M.S. are 24 hours of coursework and six credit hours of thesis research. The non-thesis option requires 30 credit hours of coursework. A maximum of six credit hours of Independent Study can be used to fulfill degree requirements. There are three tracks in Electrical Engineering: (1) Antennas and Wireless Communications (AWC), (2) Energy Systems and Power Electronics (EPSE), and (3) Information and Systems Sciences (ISS). Students are encouraged to decide between tracks before pursuing an advanced degree. Students are also encouraged to speak to their Advisor and/or a member of the EE faculty before registering for classes and to select a permanent Advisor as soon as possible. The following set of courses is required of all students.

M.S. Thesis - Electrical Engineering

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>EENG707</td>
<td>GRADUATE THESIS / DISSERTATION</td>
<td>6.0</td>
</tr>
<tr>
<td>RESEARCH CREDIT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE CORE: EE Core Courses (AWC track)</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>EE CORE: EE Core Courses (ESPE track)</td>
<td>6.0</td>
<td></td>
</tr>
<tr>
<td>EE CORE: EE Core Courses (ISS track)</td>
<td>12.0</td>
<td></td>
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</tbody>
</table>
The purpose of the Qualifying Exam is to assess some of the attributes expected of a successful Ph.D. student, including:

- To determine the student's ability to review, synthesize and apply fundamental concepts.
- To determine the creative and technical potential of the student to solve open-ended and challenging problems.
- To determine the student's technical communication skills.

The Qualifying Examination includes both written and oral sections. The written section is based on material from the EECS Department's undergraduate Electrical Engineering degree. The oral part of the exam covers one or more papers from the literature chosen by the student and the student's Advisor. The student's Advisor and two additional Electrical Engineering faculty members (typically from the student's Thesis Committee representing their track) administer the oral exam.

Ph.D. Qualifying exams will be held each spring semester. In the event of a student failing the Qualifying exam, she/he will be given one further opportunity to pass the exam in the following spring semester. If a second failure occurs, the student has unsatisfactory academic performance that results in an immediate, mandatory dismissal of the graduate student from the Ph.D. program.

Ph.D. Thesis Proposal: After passing the Qualifying Examination, the Ph.D. student is allowed up to 18 months to prepare a written Thesis Proposal and present it formally to the student's graduate committee and other interested faculty.

Admission to Candidacy: In addition to the Graduate School requirements, full-time students must complete the following requirements within two calendar years of enrolling in the Ph.D. program.

- Have a Thesis Committee appointment form on file in the Graduate Office:
- Have passed the Ph.D. Qualifying Exam demonstrating adequate preparation for, and satisfactory ability to conduct doctoral research.

Ph.D. Thesis Defense: At the conclusion of the student's Ph.D. program, the student will be required to make a formal presentation and defense of her/his thesis research.

Electrical Engineering Courses

**Required Core: Antennas and Wireless Communications Track**

All students must take 3 the following courses.

Advanced Engineering Electromagnetics
Computational Electromagnetics
Antennas

and choose at least one of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG515</td>
<td>MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>EENG527</td>
<td>WIRELESS COMMUNICATIONS</td>
<td>3.0</td>
</tr>
<tr>
<td>EENG535</td>
<td>RF AND MICROWAVE ENGINEERING</td>
<td>3.0</td>
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</tbody>
</table>

Radar Systems (to be approved for 2015-16 academic year)

**Required Core: Energy Systems and Power Electronics Track**

Choose at least 2 of the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EENG570</td>
<td>ADVANCED HIGH POWER ELECTRONICS</td>
<td>3.0</td>
</tr>
<tr>
<td>EENG580</td>
<td>POWER DISTRIBUTION SYSTEMS ENGINEERING</td>
<td>3.0</td>
</tr>
</tbody>
</table>
EENG581 POWER SYSTEM OPERATION AND MANAGEMENT 3.0

Required Core: Information and Systems Sciences Track

All students must take:

EENG515 MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS 3.0

and choose at least 3 of the following:

EENG509 SPARSE SIGNAL PROCESSING 3.0
EENG510 IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING 3.0
EENG517 THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS 3.0
EENG519 ESTIMATION THEORY AND KALMAN FILTERING 3.0
MATH534 MATHEMATICAL STATISTICS I 3.0
MEGN544 ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL 3.0

Other EE Courses:

EENG512 COMPUTER VISION 3.0
EENG535 RF AND MICROWAVE ENGINEERING 3.0
MEGN540 MECHATRONICS 3.0
MEGN545 ADVANCED ROBOT CONTROL 3.0
EGGN589 DESIGN AND CONTROL OF WIND ENERGY SYSTEMS 3.0
EENG617 INTELLIGENT CONTROL SYSTEMS 3.0
EENG618 NONLINEAR AND ADAPTIVE CONTROL 3.0
EENG683 COMPUTER METHODS IN ELECTRIC POWER SYSTEMS 3.0

Interim Department Head and Professor
Atif Elsherbeni, Dobelman Chair

Professors
Kevin Moore, College Dean
Tracy Camp
Randy Haupt
Dinesh Mehta
P.K. Sen
Tyrone Vincent

Associate Professors
Qi Han
William Hoff
Kathryn Johnson
Marcelo Simoes

Michael Wakin
Assistant Professors
Salman Mohagheghi
Payam Nayeri
Gongguo Tang
Hua Wang
Bo Wu
Dejun Yang
Chuan Yue
Hao Zhang

Teaching Professors
Ravel Ammerman
Vibhuti Dave
Cyndi Rader
Jeff Schowalter

Teaching Associate Professors
Stephanie Claussen
Keith Hellman
Christopher Painter-Wakefield
Jeffrey Paone

Emeritus Associate Professor
Catherine Skokan

Courses
CSC510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN510,
(i) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 3 hours lecture; 3 semester hours.
CSCI512. COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with EGGN512.
(I) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptors from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 3 hours lecture; 3 semester hours.

CSCI522. INTRODUCTION TO USABILITY RESEARCH. 3.0 Semester Hrs.
(I) An introduction to the field of Human-Computer Interaction (HCI).
Students will review current literature from prominent researchers in HCI and will discuss how the researchers' results may be applied to the students' own software design efforts. Topics include usability testing, ubiquitous computing user experience design, cognitive walkthrough and talk-aloud testing methodologies. Students will work in small teams to develop and evaluate an innovative product or to conduct an extensive usability analysis of an existing product. Project results will be reported in a paper formatted for submission to an appropriate conference (UbiComp, SIGCSE, CHI, etc.). Prerequisite: CSCI 261 or equivalent. 3 hours lecture, 3 semester hours.

CSCI542. SIMULATION. 3.0 Semester Hrs.
Equivalent with MACS542.
(I) Advanced study of computational and mathematical techniques for modeling, simulating, and analyzing the performance of various systems. Simulation permits the evaluation of performance prior to the implementation of a system; it permits the comparison of various operational alternatives without perturbing the real system. Topics to be covered include simulation techniques, random number generation, Monte Carlo simulations, discrete and continuous stochastic models, and point/interval estimation. Offered every other year. Prerequisite: CSCI 262 (or equivalent) and MATH 323 (or MATH 530 or equivalent). 3 hours lecture; 3 semester hours.

CSCI544. ADVANCED COMPUTER GRAPHICS. 3.0 Semester Hrs.
Equivalent with MATH544.
This is an advanced computer graphics course in which students will learn a variety of mathematical and algorithmic techniques that can be used to solve fundamental problems in computer graphics. Topics include global illumination, GPU programming, geometry acquisition and processing, point based graphics and non-photorealistic rendering. Students will learn about modern rendering and geometric modeling techniques by reading and discussing research papers and implementing one or more of the algorithms described in the literature.

CSCI546. WEB PROGRAMMING II. 3.0 Semester Hrs.
(I) This course covers methods for creating effective and dynamic web pages, and using those sites as part of a research agenda related to Humanitarian Engineering. Students will review current literature from the International Symposium on Technology and Society (ISTAS), American Society for Engineering Education (ASEE), and other sources to develop a research agenda for the semester. Following a brief survey of web programming languages, including HTML, CSS, JavaScript and Flash, students will design and implement a website to meet their research agenda. The final product will be a research paper which documents the students' efforts and research results. Prerequisite: CSCI 262. 3 hours lecture, 3 semester hours.

CSCI547. SCIENTIFIC VISUALIZATION. 3.0 Semester Hrs.
Equivalent with MATH547.
Scientific visualization uses computer graphics to create visual images which aid in understanding of complex, often massive numerical representation of scientific concepts or results. The main focus of this course is on techniques applicable to spatial data such as scalar, vector and tensor fields. Topics include volume rendering, texture based methods for vector and tensor field visualization, and scalar and vector field topology. Students will learn about modern visualization techniques by reading and discussing research papers and implementing one of the algorithms described in the literature.

CSCI555. GAME THEORY AND NETWORKS. 3.0 Semester Hrs.
(I) An introduction to fundamental concepts of game theory with a focus on the applications in networks. Game theory is the study that analyzes the strategic interactions among autonomous decision-makers. Originated from economics. Influenced many areas in Computer Science, including artificial intelligence, e-commerce, theory, and security and privacy. Provides tools and knowledge for modeling and analyzing real-world problems. Prerequisites: CSCI406 Algorithms. 3 hours lecture; 3 semester hours.

CSCI561. THEORY OF COMPUTATION. 3.0 Semester Hrs.
(I) An introduction to abstract models of computation and computability theory; including finite automata (finite state machines), pushdown automata, and Turing machines. Language models, including formal languages, regular expressions, and grammars. Decidability and undecidability of computational problems. Prerequisite: CSCI/MATH358. 3 hours lecture; 3 semester hours.

CSCI562. APPLIED ALGORITHMS AND DATA STRUCTURES. 3.0 Semester Hrs.
(II) Industry competitiveness in certain areas is often based on the use of better algorithms and data structures. The objective of this class is to survey some interesting application areas and to understand the core algorithms and data structures that support these applications. Application areas could change with each offering of the class, but would include some of the following: VLSI design automation, computational biology, mobile computing, computer security, data compression, web search engines, geographical information systems. Prerequisite: MATH/ CSCI406. 3 hours lecture; 3 semester hours.
CSCI563. PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS. 3.0 Semester Hrs.
(I) Students are taught how to use parallel computing to solve complex scientific problems. They learn how to develop parallel programs, how to analyze their performance, and how to optimize program performance. The course covers the classification of parallel computers, shared memory versus distributed memory machines, software issues, and hardware issues in parallel computing. Students write programs for state of the art high performance supercomputers, which are accessed over the network. Prerequisite: Programming experience in C. 3 hours lecture; 3 semester hours.

CSCI564. ADVANCED COMPUTER ARCHITECTURE. 3.0 Semester Hrs.
The objective of this class is to gain a detailed understanding about the options available to a computer architect when designing a computer system along with quantitative justifications for the options. All aspects of modern computer architectures including instruction sets, processor design, memory system design, storage system design, multiprocessors, and software approaches will be discussed. Prerequisite: CSCI41. 3 hours lecture; 3 semester hours.

CSCI565. DISTRIBUTED COMPUTING SYSTEMS. 3.0 Semester Hrs.
(II) This course discusses concepts, techniques, and issues in developing distributed systems in large scale networked environment. Topics include theory and systems level issues in the design and implementation of distributed systems. Prerequisites: CSCI 442 or equivalent. 3 hours of lecture; 3 semester hours.

CSCI568. DATA MINING. 3.0 Semester Hrs.
Equivalent with MACS568,
(II) This course is an introductory course in data mining. It covers fundamentals of data mining theories and techniques. We will discuss association rule mining and its applications, overview of classification and clustering, data preprocessing, and several application-specific data mining tasks. We will also discuss practical data mining using a data mining software. Project assignments include implementation of existing data mining algorithms, data mining with or without data mining software, and study of data mining related research issues. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI571. ARTIFICIAL INTELLIGENCE. 3.0 Semester Hrs.
(I) Artificial Intelligence (AI) is the subfield of computer science that studies how to automate tasks for which people currently exhibit superior performance over computers. Historically, AI has studied problems such as machine learning, language understanding, game playing, planning, robotics, and machine vision. AI techniques include those for uncertainty management, automated theorem proving, heuristic search, neural networks, and simulation of expert performance in specialized domains like medical diagnosis. This course provides an overview of the field of Artificial Intelligence. Particular attention will be paid to learning the LISP language for AI programming. Prerequisite: CSCI262. 3 hours lecture; 3 semester hours.

CSCI572. COMPUTER NETWORKS II. 3.0 Semester Hrs.
Equivalent with MACS572,
(II) This course covers the network layer, data link layer, and physical layer of communication protocols in depth. Detailed topics include routing (unicast, multicast, and broadcast), one hop error detection and correction, and physical topologies. Other topics include state-of-the-art communications protocols for emerging networks (e.g., ad hoc networks and sensor networks). Prerequisite: CSCI 471 or equivalent. 3 hours lecture; 3 semester hours.

CSCI573. HUMAN-CENTERED ROBOTICS. 3.0 Semester Hrs.
Equivalent with CSCI473,
(I) Human-centered robotics is an interdisciplinary area that bridges research and application of methodology from robotics, machine vision, machine learning, human-computer interaction, human factors, and cognitive science. Students will learn about fundamental research in human-centered robotics, as well as develop computational models for robotic perception, internal representation, robotic learning, human-robot interaction, and robot cognition for decision making. Students in CSCI 473 will be able to model and analyze human behaviors geared toward human-robot interaction applications. They will also be able to implement a working system using algorithms learnt to solve a given problem in human-centered robotics application. Students in CSCI 573 will get a more in-depth study into the theory of the algorithms. They will be able to compare the different algorithms to select the most appropriate one that can solve a specific problem. Prerequisites: CSCI262 and MATH201 (or equivalent). 3 hours lecture; 3 semester hours.

CSCI574. THEORY OF CRYPTOGRAPHY. 3.0 Semester Hrs.
Equivalent with MATH574,
Students will draw upon current research results to design, implement and analyze their own computer security or other related cryptography projects. The requisite mathematical background, including relevant aspects of number theory and mathematical statistics, will be covered in lecture. Students will be expected to review current literature from prominent researchers in cryptography and to present their findings to the class. Particular focus will be given to the application of various techniques to real-life situations. The course will also cover the following aspects of cryptography: symmetric and asymmetric encryption, computational number theory, quantum encryption, RSA and discrete log systems, SHA, steganography, chaotic and pseudo-random sequences, message authentication, digital signatures, key distribution and key management, and block ciphers. Prerequisites: CSCI 262 plus undergraduate-level knowledge of statistics and discrete mathematics. 3 hours lecture, 3 semester hours.

CSCI575. MACHINE LEARNING. 3.0 Semester Hrs.
Equivalent with MACS575,
(II) The goal of machine learning research is to build computer systems that learn from experience and that adapt to their environments. Machine learning systems do not have to be programmed by humans to solve a problem; instead, they essentially program themselves based on examples of how they should behave, or based on trial and error experience trying to solve the problem. This course will focus on the methods that have proven valuable and successful in practical applications. The course will also contrast the various methods, with the aim of explaining the situations in which each is most appropriate. Prerequisites: CSCI262 and MATH201. 3 hours lecture; 3 semester hours.
CSCI576. WIRELESS SENSOR SYSTEMS. 3.0 Semester Hrs.
With the advances in computational, communication, and sensing capabilities, large scale sensor-based distributed environments are becoming a reality. Sensor enriched communication and information infrastructures have the potential to revolutionize almost every aspect of human life benefiting application domains such as transportation, medicine, surveillance, security, defense, science and engineering. Such a distributed infrastructure must integrate networking, embedded systems, distributed computing and data management technologies to ensure seamless access to data dispersed across a hierarchy of storage, communication, and processing units, from sensor devices where data originates to large databases where the data generated is stored and/or analyzed. Prerequisite: CSCI406, CSCI446, CSCI471. 3 hours lecture; 3 semester hours.

CSCI580. ADVANCED HIGH PERFORMANCE COMPUTING. 3.0 Semester Hrs.
This course provides students with knowledge of the fundamental concepts of high performance computing as well as hands-on experience with the core technology in the field. The objective of this class is to understand how to achieve high performance on a wide range of computational platforms. Topics will include sequential computers including memory hierarchies, shared memory computers and multicore, distributed memory computers, graphical processing units (GPUs), cloud and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

CSCI586. FAULT TOLERANT COMPUTING. 3.0 Semester Hrs.
This course provides a comprehensive overview of fault tolerant computing including uniprocessor fault tolerance, distributed fault tolerance, failure model, fault detection, checkpoint, message log, algorithm-based fault tolerance, error correction codes, and fault tolerance in large storage systems. 3 hours lecture; 3 semester hours.

CSCI597. SUMMER PROGRAMS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI598. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different topics.

CSCI599. INDEPENDENT STUDY. 0.5-6 Semester Hrs.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI691. GRADUATE SEMINAR. 1.0 Semester Hr.
Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI692. GRADUATE SEMINAR. 1.0 Semester Hr.
Equivalent with MACS692,MATH692, Presentation of latest research results by guest lecturers, staff, and advanced students. Prerequisite: none. 1 hour seminar; 1 semester hour. Repeatable for credit to a maximum of 12 hours.

CSCI693. WAVE PHENOMENA SEMINAR. 1.0 Semester Hr.
Students will probe a range of current methodologies and issues in seismic data processing, with emphasis on underlying assumptions, implications of these assumptions, and implications that would follow from use of alternative assumptions. Such analysis should provide seed topics for ongoing and subsequent research. Topic areas include: Statistics estimation and compensation, deconvolution, multiple suppression, suppression of other noises, wavelet estimation, imaging and inversion, extraction of stratigraphic and lithologic information, and correlation of surface and borehole seismic data with well log data. Prerequisite: none. 1 hour seminar; 1 semester hour.

CSCI698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

CSCI699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

CSCI700. MASTERS PROJECT CREDITS. 1-6 Semester Hr.
(I, II, S) Project credit hours required for completion of the non-thesis Master of Science degree in Computer Science (Project Option). Project under the direct supervision of a faculty advisor. Credit is not transferable to any 400, 500, or 600 level courses. Repeatable for credit.

CSCI707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) GRADUATE THESIS/DISSERTATION RESEARCH CREDIT Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

EENG504. ENGINEERING SYSTEMS SEMINAR - ELECTRICAL. 1.0 Semester Hr.
Equivalent with EGGN504E, (I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.

EENG504. ENGINEERING SYSTEMS SEMINAR - ELECTRICAL. 1.0 Semester Hr.
Equivalent with EGGN504E, (I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering and grid computing, threads, OpenMP, message passing (MPI), CUDA (for GPUs), parallel file systems, and scientific applications. 3 hours lecture; 3 semester hours.
EENG509. SPARSE SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with EGGN509.
(I, II) This course presents a mathematical tour of sparse signal representations and their applications in modern signal processing. The classical Fourier transform and traditional digital signal processing techniques are extended to enable various types of computational harmonic analysis. Topics covered include time-frequency and wavelet analysis, filter banks, non-linear approximation of functions, compression, signal restoration, and compressive sensing. Prerequisites: EENG411 and EENG515. 3 hours lecture; 3 semester hours.

EENG510. IMAGE AND MULTIDIMENSIONAL SIGNAL PROCESSING. 3.0 Semester Hrs.
Equivalent with CSCS510, EGGN510.
(I) This course provides the student with the theoretical background to allow them to apply state of the art image and multi-dimensional signal processing techniques. The course teaches students to solve practical problems involving the processing of multidimensional data such as imagery, video sequences, and volumetric data. The types of problems students are expected to solve are automated mensuration from multidimensional data, and the restoration, reconstruction, or compression of multidimensional data. The tools used in solving these problems include a variety of feature extraction methods, filtering techniques, segmentation techniques, and transform methods. Students will use the techniques covered in this course to solve practical problems in projects. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, Fourier transforms, and a programming language. 3 hours lecture; 3 semester hours.

EENG511. CONVEX OPTIMIZATION AND ITS ENGINEERING APPLICATIONS. 3.0 Semester Hrs.
(II) The course focuses on recognizing and solving convex optimization problems that arise in applications in various engineering fields. Covered topics include basic convex analysis, conic programming, duality theory, unconstrained optimization, and constrained optimization. The application part covers problems in signal processing, power and energy, machine learning, control and mechanical engineering, and other fields, with an emphasis on modeling and solving these problems using the CVX package. Prerequisites: EENG311 and EENG511. 3 hours lecture; 3 semester hours.

EENG512. COMPUTER VISION. 3.0 Semester Hrs.
Equivalent with CSCIS512, EGGN512.
(II) Computer vision is the process of using computers to acquire images, transform images, and extract symbolic descriptions from images. This course concentrates on how to recover the structure and properties of a possibly dynamic three-dimensional world from its two-dimensional images. We start with an overview of image formation and low level image processing, including feature extraction techniques. We then go into detail on the theory and techniques for estimating shape, location, motion, and recognizing objects. Applications and case studies will be discussed from scientific image analysis, robotics, machine vision inspection systems, photogrammetry, multimedia, and human interfaces (such as face and gesture recognition). Design ability and hands-on projects will be emphasized, using image processing software and hardware systems. Prerequisite: Undergraduate level knowledge of linear algebra, probability and statistics, and a programming language. 3 hours lecture; 3 semester hours.

EENG515. MATHEMATICAL METHODS FOR SIGNALS AND SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN515.
(I) An introduction to mathematical methods for modern signal processing using vector space methods. Topics include signal representation in Hilbert and Banach spaces; linear operators and the geometry of linear equations; LU, Cholesky, QR, eigen- and singular value decompositions. Applications to signal processing and linear systems are included throughout, such as Fourier analysis, wavelets, adaptive filtering, signal detection, and feedback control.

EENG517. THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN517.
(II) This course will introduce and study the theory and design of multivariable and nonlinear control systems. Students will learn to design multivariable controllers that are both optimal and robust, using tools such as state space and transfer matrix models, nonlinear analysis, optimal estimator and controller design, and multi-loop controller synthesis. Prerequisite: EENG417. 3 hours lecture; 3 semester hours.

EENG519. ESTIMATION THEORY AND KALMAN FILTERING. 3.0 Semester Hrs.
Equivalent with EGGN519.
Estimation theory considers the extraction of useful information from raw sensor measurements in the presence of signal uncertainty. Common applications include navigation, localization and mapping, but applications can be found in all fields where measurements are used. Mathematical descriptions of random signals and the response of linear systems are presented. The discrete-time Kalman Filter is introduced, and conditions for optimality are described. Implementation issues, performance prediction, and filter divergence are discussed. Adaptive estimation and nonlinear estimation are also covered. Contemporary applications will be utilized throughout the course. Pre-requisite: EENG515 and MATH534 or equivalent. Spring semester of odd years. 3 Lecture Hours; 3 Semester Hours.

EENG525. ANTENNAS. 3.0 Semester Hrs.
(I, II) This course provides an in depth introduction to the analysis and synthesis of antennas and antenna arrays. Students are expected to use MATLAB to model antennas and their performance. An extensive final project that involves experimental or computer demonstrations is required. EENG525 has more depth and required work than EENG425. EENG525 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on antenna and direction finding projects. Prerequisites: EGGN386 or GPGN302 or PHGN384. 3 hours lecture; 3 semester hours.

EENG527. WIRELESS COMMUNICATIONS. 3.0 Semester Hrs.
Equivalent with EENG513, EGGN513.
(I, II) This course provides the tools needed to analyze and design a wireless system. Topics include link budgets, satellite communications, cellular communications, handsets, base stations, modulation techniques, RF propagation, coding, and diversity. Students are expected to complete an extensive final project. EENG527 has more depth and required work than EENG427. EENG527 students will have one additional problem for each homework assignment, one additional problem on exam, more difficult paper to review and present, and higher expectations on final project. Prerequisites: EENG386, EENG311, and EENG388. 3 hours lecture; 3 semester hours.
EENG535. RF AND MICROWAVE ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN516.
This course teaches the basics of RF/microwave design including circuit concepts, modeling techniques, and test and measurement techniques, as applied to wireless communication systems. RF/microwave concepts that will be discussed are: scattering parameters, impedance matching, microstrip and coplanar transmission lines, power dividers and couplers, filters, amplifiers, oscillators, and diode mixers and detectors. Students will learn how to design and model RF/microwave components such as impedance matching networks, amplifiers and oscillators on Ansoft Designer software, and will build and measure these circuits in the laboratory. Prerequisites: EENG385, EENG386, EENG413. 3 hours lecture, 3 semester hours. Taught on demand.

EENG570. ADVANCED HIGH POWER ELECTRONICS. 3.0 Semester Hrs.
Equivalent with EGGN585,
(I) Basic principles of analysis and design of circuits utilizing high power electronics. AC/DC, DC/AC, AC/AC, and DC/DC conversion techniques. Laboratory project comprising simulation and construction of a power electronics circuit. Prerequisites: EENG385; EENG389 or equivalent. 3 hours lecture; 3 semester hours. Fall semester even years.

EENG571. MODERN ADJUSTABLE SPEED ELECTRIC DRIVES. 3.0 Semester Hrs.
Equivalent with EGGN581,
An introduction to electric drive systems for advanced applications. The course introduces the treatment of vector control of induction and synchronous motor drives using the concepts of general flux orientation and the feedforward (indirect) and feedback (direct) voltage and current vector control. AC models in space vector complex algebra are also developed. Other types of drives are also covered, such as reluctance, stepper-motor and switched-reluctance drives. Digital computer simulations are used to evaluate such implementations. Pre-requisite: Familiarity with power electronics and power systems, such as covered in EENG480 and EENG470. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG572. RENEWABLE ENERGY AND DISTRIBUTED GENERATION. 3.0 Semester Hrs.
Equivalent with EGGN582,
A comprehensive electrical engineering approach on the integration of alternative sources of energy. One of the main objectives of this course is to focus on the inter-disciplinary aspects of integration of the alternative sources of energy which will include most common and also promising types of alternative primary energy: hydropower, wind power, photovoltaic, fuel cells and energy storage with the integration to the electric grid. Pre-requisite: It is assumed that students will have some basic and broad knowledge of the principles of electrical machines, thermodynamics, power electronics, direct energy conversion, and fundamentals of electric power systems such as covered in basic engineering courses plus EENG480 and EENG470. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG573. ELECTRIC POWER QUALITY. 3.0 Semester Hrs.
Equivalent with EGGN580,
(II) Electric power quality (PQ) deals with problems exhibited by voltage, current and frequency that typically impact end-users (customers) of an electric power system. This course is designed to familiarize the concepts of voltage sags, harmonics, momentary disruptions, and waveform distortions arising from various sources in the system. A theoretical and mathematical basis for various indices, standards, models, analyses techniques, and good design procedures will be presented. Additionally, sources of power quality problems and some remedies for improvement will be discussed. The course bridges topics between power systems and power electronics. Prerequisite: EENG480 and EENG470. 3 lecture hours; 3 semester hours.

EENG580. POWER DISTRIBUTION SYSTEMS ENGINEERING. 3.0 Semester Hrs.
Equivalent with EGGN584,
This course deals with the theory and applications of problems and solutions as related to electric power distribution systems engineering from both ends: end-users like large industrial plants and electric utility companies. The primary focus of this course in on the medium voltage (4.16 kV ? 69 kV) power systems. Some references will be made to the LV power system. The course includes per-unit methods of calculations; voltage drop and voltage regulation; power factor improvement and shunt compensation; short circuit calculations; theory and fundamentals of symmetrical components; unsymmetrical faults; overhead distribution lines and power cables; basics and fundamentals of distribution protection. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of odd years.

EENG581. POWER SYSTEM OPERATION AND MANAGEMENT. 3.0 Semester Hrs.
Equivalent with EGGN587,
(I) This course presents a comprehensive exposition of the theory, methods, and algorithms for Energy Management Systems (EMS) in the power grid. It will focus on (1) modeling of power systems and generation units, (2) methods for dispatching generating resources, (3) methods for accurately estimating the state of the system, (4) methods for assessing the security of the power system, and (5) an overview of the market operations in the grid. Prerequisite: EENG480. 3 lecture hours; 3 semester hours.

EENG582. HIGH VOLTAGE AC AND DC POWER TRANSMISSION. 3.0 Semester Hrs.
Equivalent with EGGN586,
This course deals with the theory, modeling and applications of HV and EHV power transmission systems engineering. The primary focus is on overhead AC transmission line and voltage ranges between 115 kV ? 500 kV. HVDC and underground transmission will also be discussed. The details include the calculations of line parameters (RLC); steady-state performance evaluation (voltage drop and regulation, losses and efficiency) of short, medium and long lines; reactive power compensation; FACTS devices; insulation coordination; corona; insulated cables; sag-tension calculations; EMTP, traveling wave and transients; fundamentals of transmission line design; HV and EHV power cables: solid dielectric, oil-filled and gas-filled; Fundamentals of DC transmission systems including converter and filter. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Fall semester of even years.
EENG583. ADVANCED ELECTRICAL MACHINE DYNAMICS. 3.0 Semester Hrs.
Equivalent with EGGN583.
This course deals primarily with the two rotating AC machines currently utilized in the electric power industry, namely induction and synchronous machines. The course is divided into two halves: the first half is dedicated to induction and synchronous machines are taught in the second half. The details include the development of the theory of operation, equivalent circuit models for both steady-state and transient operations, all aspects of performance evaluation, IEEE methods of testing, and guidelines for industry applications including design and procurement. Prerequisites: EENG480 or equivalent. 3 lecture hours; 3 semester hours. Spring semester of even years.

EENG584. POWER SYSTEM STABILITY. 3.0 Semester Hrs.
Advanced topics on stability of power and energy systems, including dynamic modeling of generators and motors, small signal stability of power system, transient stability during and in the aftermath of disturbances, voltage stability and voltage collapse, blackouts and brownouts in the bulk power grid, subsynchronous resonance, and impacts of distributed and renewable energy resources on grid stability. Prerequisites: EENG480, EENG481. 3 hours of lecture; 3 credit hours. Spring, even years.

EENG586. COMMUNICATION NETWORKS FOR POWER SYSTEMS. 3.0 Semester Hrs.
Advanced topics on communication networks for power systems including the fundamentals of communication engineering and signal modulation/transfer, physical layer for data transfer (e.g., wireline, wireless, fiber optics), different communication topologies for power networks (e.g., client-server, peer-to-peer), fundamentals of SCADA system, data modeling and communication services for power system applications, common protocols for utility and substation automation, and cybersecurity in power networks. Prerequisites: EENG480. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG587. POWER SYSTEMS PROTECTION AND RELAYING. 3.0 Semester Hrs.
Theory and practice of power system protection and relaying; Study of power system faults and symmetrical components; Fundamental principles and tools for system modeling and analysis pertaining to relaying, and industry practices in the protection of lines, transformers, generators, motors, and industrial power systems; Introduction to microprocessor based relaying, control, and SCADA. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Spring, odd years.

EENG588. ENERGY POLICY, RESTRUCTURING AND Deregulation of ELECTRICITY MARKET. 3.0 Semester Hrs.
The big picture of electric power, electricity and energy industry; Restructuring and Deregulation of electricity market; Energy Policy Acts and its impact on electricity market and pricing; Energy economics and pricing strategy; Public policy issues, reliability and security; Regulation. Prerequisites: EENG389. 3 hours of lecture; 3 credit hours. Fall, odd years.

EENG597. SUMMER PROGRAMS. 6.0 Semester Hrs.
EENG598. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EENG599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG617. INTELLIGENT CONTROL SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN617.
Fundamental issues related to the design on intelligent control systems are described. Neural networks analysis for engi neering systems are presented. Neural-based learning, estimation, and identification of dynamical systems are described. Qualitative control system analysis using fuzzy logic is presented. Fuzzy mathematics design of rule-based control, and integrated human-machine intelligent control systems are covered. Real-life problems from different engineering systems are analyzed. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Taught on demand.

EENG618. NONLINEAR AND ADAPTIVE CONTROL. 3.0 Semester Hrs.
Equivalent with EGGN618.
This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and the applications of this theory to adaptive control. It will focus on (1) methods of characterizing and understanding the behavior of systems that can be described by nonlinear ordinary differential equations, (2) methods for designing controllers for such systems, (3) an introduction to the topic of system identification, and (4) study of the primary techniques in adaptive control, including model-reference adaptive control and model predictive control. Prerequisite: EENG517. 3 hours lecture; 3 semester hours. Spring, even numbered years.

EENG683. COMPUTER METHODS IN ELECTRIC POWER SYSTEMS. 3.0 Semester Hrs.
Equivalent with EGGN583.
This course deals with the computer methods and numerical solution techniques applied to large scale power systems. Primary focus includes load flow, short circuit, voltage stability and transient stability studies and contingency analysis. The details include the modeling of various devices like transformer, transmission lines, FACTS devices, and synchronous machines. Numerical techniques include solving a large set of linear or non-linear algebraic equations, and solving a large set of differential equations. A number of simple case studies (as per IEEE standard models) will be performed. Prerequisites: EENG583, EENG580 and EENG582 or equivalent; a strong knowledge of digital simulation techniques. 3 lecture hours; 3 semester hours. Taught on demand.

EENG698. SPECIAL TOPICS IN ELECTRICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.
EENG699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

EENG707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
Equivalent with EGGN707E.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.

SYGN555. SMARTGEO SEMINAR. 1.0 Semester Hr.
Geosystems are natural or engineered earth structures, e.g. earth dams or levees, groundwater systems, underground construction sites, and contaminated aquifers. An intelligent geosystem is one that can sense its environment, diagnose its condition/state, and provide decision support to improve the management, operation, or objective of the geosystem. The goal of this course is to introduce students to topics that are needed for them to be successful working in a multi-disciplinary field. The course will include training in leadership, multidisciplinary teams, policy and ethical issues, and a monthly technical seminar. Prerequisite/Corequisite: SYGN550. 1 hour lecture; 1 semester hour credit.