ELECTRICAL ENGINEERING

The mission of the electrical engineering program, consistent with the Missouri S&T campus mission statements, is the education of students to fully prepare them to provide leadership in the recognition and solution of society’s problems in the area of electrical engineering.

The electrical engineering program in the department of electrical and computer engineering offers graduate programs of study which lead to the M.S. degree (thesis and non-thesis options), the Ph.D. degree and the doctor of engineering degree. Both, the Rolla campus and the Engineering Education Center in St. Louis offer M.S. programs. Most graduate programs in electrical engineering normally include some specialization in one or more of the following six emphasis areas of electrical engineering.

Emphasis Areas

Circuits
Topics include network analysis and synthesis, computer-aided circuit design, communications circuits, and linear and nonlinear electronic circuits.

Communications & Signal Processing
Topics include signal design, coding, modulation, detection, and filtering for both analog and digital systems.

Computer Engineering
Computer engineering can be an emphasis area in electrical engineering or a separate degree. See the section on computer engineering for emphasis areas in computer engineering.

Control Systems Technology
Our technological demands today impose extremely challenging and widely varying control problems. These problems include control of aircraft, space and underwater vehicles, automobiles, chemical processes, manufacturing, robotics, environmental systems, and smart structural systems. Control systems engineering studies will emphasize linear and nonlinear systems, digital control, process control system simulation, optimal control and estimation, robust control, neural networks and fuzzy logic based control systems, and control of smart structures.

Electromagnetics
Electromagnetics, devices, and optics constitute a single emphasis area in the electrical and computer engineering department. Electromagnetic topics include the generation, propagation, and detection of electromagnetic fields and waves. In addition to the intentional generation of electromagnetic waves, unintentional electromagnetic radiation can occur. This unintentional radiation often accompanies the operation of high-speed digital electronic circuits. Electromagnetic compatibility is concerned with the removal or reduction of these unintentional and undesirable effects. The devices portion of this area is concerned with modeling and development of new electronic components as well as the characterization and growth of semiconductor materials. Optical topics include applications of fiber optics, optical processing, optical computing, and smart sensing. Fiber optic telecommunications encompass waveguides, photonic sources and detectors, and modulation and control techniques. Smart sensing deals with physical measurements in structures using integral optical devices. Signals at microwave and millimeter wave frequencies can be effectively used for nondestructive testing (NDT), evaluation (NDE) and inspection (NDI) of a variety of materials ranging from low loss dielectric composites for material property and interior flaw determination to highly conducting materials such as metals for surface cracks detection. High spatial resolution microwave images of composite materials can also be produced when operating in the near-field region of a radiator.

Electronics
Topics include circuits and networks containing active devices. Typical applications might include radio frequency amplifiers, oscillators, active filters, and others. These circuits and networks can be either digital or analog in nature.

Power
Power studies include application of computer methods to power system analysis and control, power system relaying and protection, power quality load management, finite inertia power systems (such as those on ships, hybrid electric vehicles, and spacecraft), and electromechanical energy conversion devices (such as rotating machinery, power electronic converters, and electric drive systems).

Departmental Requirements

Admission Requirements

The nominal GPA requirement for admission to the M.S. degree program in this department is an undergraduate GPA of 3.3 on a 4.0 GPA system. In evaluating the academic performance from universities that may use other grading systems, the department may rely upon statistical data gathered in analyzing academic outcomes for recent graduate students to the extent that such statistical data is available. The department will not offer graduate admissions to students who do not have the equivalent of a four year baccalaureate degree in engineering. As an example, we cannot accept students who have only a diploma or engineering technology degree.

In addition to campus requirements that the sum of GRE-V and GRE-Q be 1100 and the GRE-WR score be a minimum of 3.5, the ECE department requires ETS reported GRE scores and recommends the following:

ETS scoring prior to November 2011: Q+V=1110, Q≥ 760, V=420

ETS scoring after November 2011: Q+V=308, Q≥ 160, V=148, A/WR ≥ 4.0

For international students who are required to provide TOEFL scores, the ECE department has no preference as to the computer based TOEFL (CBT), internet based TOEFL (iBT), or paper based TOEFL (PBT). Minimum recommended scores set by the department are 237 CBT, 92 iBT, and 580 PBT. Where TOEFL is not available, IELTS score of ≥ 6.5 is recommended.

Students applying for graduate studies in this department on the basis of degrees in closely related fields may have additional conditions placed on their admission. These conditions are generally imposed to make sure that students lacking a traditional electrical engineering degree will have sufficient background to ensure a reasonable chance for academic success.

Students seeking admission to the Ph.D. program should meet or exceed all of the above recommendations and should have a graduate GPA of 3.5 or better. All Ph.D. applicants must provide at least three letters of
recommendation. Exceptional applicants may apply directly to the Ph.D. program after completing the baccalaureate degree.

Program Requirements
Additional departmental requirements beyond those stated in the section on Admission and Program Procedures are as follows. Thesis option M.S. programs of study require a minimum of 21 credit hours of course work exclusive of credit hours earned for thesis research (courses numbered 490). A limited number of credit hours for 200 level courses may be counted towards the fulfillment of a M.S. program of study, provided that the courses are taken outside of the electrical and computer engineering department and that the courses are pre-requisites for at least one 300 or 400 level course also included in the program of study. The doctoral program of study, for the Ph.D. degree or the D.E. degree, should include 90 credit hours beyond the B.S. degree or 60 credit hours beyond the M.S. degree. An M.S. or doctoral student's advisory committee may impose additional requirements or restrictions as it sees fit.

Ph.D. Language Requirement
As an electrical engineering Ph.D. student, you are not required to satisfy a language requirement. However, you may have language requirements included in your plan of study if your advisory committee feels that this inclusion would be useful or necessary for your research.

Research
Significant research, suitable for publication, is expected for students pursuing the thesis option M.S. or a doctoral degree. The student should work closely with their major advisor and their advisory committee to determine when these expectations are met. The length of research time and/or the number credit hours earned for thesis research will not automatically satisfy this requirement.

Additional Information
Additional information about departmental emphasis areas, requirements, graduate handbook, faculty, research opportunities, financial aid, and facilities can be found by visiting the department's web page at http://ece.mst.edu. We can be contacted by telephone at 573-341-4519 or e-mail ecegrad@mst.edu. For information about the Engineering Education Center in St. Louis, visit their web page at http://eec.mst.edu.

Electric Machine and Drives
This graduate certificate program is designed to provide specialized graduate level education in the area of electric machine and drives.

Admission
The electric machine and drives program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program and having a minimum of 24 months of professional work experience that would normally require an engineering degree or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status; however, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program in electrical engineering if they apply. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.

Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

Curriculum
The following two courses must be taken:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEC ENG 5500</td>
<td>Electric Drive Systems</td>
</tr>
<tr>
<td>ELEC ENG 6500</td>
<td>Advanced Theory Of Electric Machines</td>
</tr>
</tbody>
</table>

A minimum of two of the following electric power systems courses must be taken:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEC ENG 5500</td>
<td>Electric Power Quality</td>
</tr>
<tr>
<td>ELEC ENG 5300</td>
<td>Digital Control</td>
</tr>
<tr>
<td>ELEC ENG 5520</td>
<td>Power Electronics</td>
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<tr>
<td>ELEC ENG 5600</td>
<td>Interference Control in Electronic Systems</td>
</tr>
<tr>
<td>ELEC ENG 6001</td>
<td>Special Topics</td>
</tr>
<tr>
<td>ELEC ENG 6550</td>
<td>Power System Stability</td>
</tr>
<tr>
<td>ELEC ENG 6300</td>
<td>Linear Control Systems</td>
</tr>
</tbody>
</table>

Other courses approved by the electric machines and drives faculty may be substituted for any of the above listed courses on a case-by-case basis. The department's associate chair for graduate affairs must approve the substitution prior to enrolling in the course.

Electrical Power Systems Engineering
This graduate certificate program is designed to provide specialized graduate level education in the area of electric power systems engineering.

Admission
The electrical power systems engineering program is open to all persons holding a B.S. degree in any field of engineering from an ABET accredited undergraduate program and having a minimum of 24 months of post B.S. professional work experience that would normally require an engineering degree or a degree in a closely related technical field such as physics or mathematics. The minimum overall GPA in the B.S. degree program should be at least 2.5.

Once admitted to the program, the student must take four designated courses as given below. In order to receive a graduate certificate, the student must have an average graduate grade point average of 3.0 or better in the certificate courses taken.

Students admitted to the certificate program will have non-degree graduate status; however, if they complete the four-course sequence with a grade of B or better in each of the courses taken, they will be admitted to the M.S. program in electrical engineering if they apply. The certificate courses taken by students admitted to the M.S. program will count towards their master's degrees. Students who do not have all of the prerequisite courses necessary to take the courses in the certificate program will be allowed to take "bridge" courses at either the graduate or undergraduate level to prepare for the formal certificate courses.
Once admitted to the program, a student will be given three years to complete the program so long as he/she maintains a B average in the courses taken.

**Curriculum**

The following two electric power systems courses must be taken:

- ELEC ENG 5540 Power Systems Engineering
- ELEC ENG 5550 Electric Power Quality

A minimum of two of the following electric power systems courses must be taken:

- ELEC ENG 6300 Linear Control Systems
- ELEC ENG 6570 Extra High Voltage Engineering
- ELEC ENG 6540 Computer Methods In Power System Analysis
- ELEC ENG 6550 Power System Stability
- ELEC ENG 6560 Power System Protection
- ELEC ENG 6570 Surge Phenomena In Power Systems
- ELEC ENG 6580 Power System Operations

Other courses approved by the electric power systems faculty may be substituted for any of the above listed courses on a case-by-case basis. The department’s associate chair for graduate affairs must approve the substitution prior to enrolling in the course.

**Levent Acar**, Associate Professor
PHD Ohio State University
Control and systems, intelligent control with applications to robotics, neural network and fuzzy logic systems, large-scale systems and optimization.

**Daryl G Beetner**, Professor
DSC Washington University
Computer Engineering, parallel processing, hardware-software co-design, skin cancer detection, and electro-cardiology. Interests in electro-cardiology include body-surface mapping, the inverse problem, and risk-assessment.

**Egemen K Cetinkaya**, Assistant Professor
PHD University of Kansas
Networks, systems, graph algorithms, resilience, and dependability.

**Minsu Choi**, Associate Professor
PHD Oklahoma State University
Computer architecture &amp; VLSI, embedded systems, fault tolerance testing, quality assurance, reliability modeling &amp; analysis, configurable computing, distributed systems, dependable instrumentation &amp; measurement.

**Mariesa L Crow**, Professor
PHD University of Illinois-Urbana
Power systems analysis, dynamic stability, computational algorithms, and power electronics.

**Kristen Marie Donnell Hilgedick**, Assistant Professor
PHD Missouri University of Science & Technology
Microwave nondestructive testing, modulated antennas/scatterers, terahertz methodologies and electronics design.

**James L Drewniak**, Curators Professor
PHD University of Illinois-Urbana
Electromagnetic compatibility of high-speed digital electronics, power electronics and electric machinery, numerical electromagnetic analysis, electronic packaging.

**Kelvin Todd Erickson**, Professor
PHD Iowa State University
Chemical process control, advanced control algorithms, digital control, programmable logic controllers, system identification.

**Jun Fan**, Associate Professor
PHD University of Missouri-Rolla
Intra-system electromagnetic compatibility, Radio-Frequency interference, signal/power integrity, high-speed printed circuit boards and packages.

**Mehdi Ferdowsi**, Associate Professor
PHD Illinois Institute of Technology
Power electronics, power converters and electric drives.

**Steven Leslie Grant**, Associate Professor
PHD Rutgers State University-College of Engineering
Telecommunications and signal processing.

**Jhi-Young Joo**, Assistant Professor
PHD Carnegie Mellon University
Power systems engineering, modeling and optimization of power systems and electricity markets, mathematical programming, energy management and resource scheduling.

**Victor Khilkevich**, Assistant Professor
PHD Moscow Power Engineering Institute
Microwave imaging, near field measurements, automotive EMC, electromagnetic interference in electronic systems, EMC material and signal integrity.

**Chang-Soo Kim**, Associate Professor
PHD Kyungpook National University
Micro-and nano-sensors, bio-MEMS (Micro Electro Mechanical System), engineering of electronic (neural and cardiac) cells, single cell analysis.

**Jonathan William Kimball**, Associate Professor
PHD University of Illinois-Urbana
Power electronics, energy harvesting, alternative energy, multi-phase converters.

**Kurt Louis Kosbar**, Associate Professor
PHD University of Southern California
Statistical communication theory, spread spectrum systems, computer aided design of communication systems, stochastic process theory, digital signal processing.

**Randy Hays Moss**, Professor
PHD University of Illinois-Urbana
Machine vision systems including industrial (vision systems for robots) and medical (computer assisted diagnosis) applications, pattern recognition, image processing, digital systems, analog and digital circuits.

**David Pommerenke**, Professor
PHD Technical University Berlin
Electromagnetic compatibility with emphasis on measurement techniques and the application of numerical methods, and the application of FR methods to high voltage problems.
Jagannathan Sarangapani, Professor
PHD University of Texas-Arlington
Control of networks, embedded systems and resilience, sensors and neural network control, diagnostics/prognostics, cyber physical systems, event-triggered control.

Sahra Sedighsarvestani, Associate Professor
PHD Purdue University-W. Lafayette
Component-based software engineering and enterprise integration.

Pourya Shamsi, Assistant Professor
PHD University of Texas-Dallas
Smart-grids, stability assessments in micro-grids, energy management, switching power converters, VHF/UHF dc-dc converters, and motor drives.

Yiyu Shi, Assistant Professor
PHD University of California-LA
VLSI design automation, 3D, ICs, and renewable energy.

Ronald Joe Stanley, Associate Professor
PHD University of Missouri-Columbia
Image processing, pattern recognition software methods, automation and medical informatics.

Steve E Watkins, Professor
PHD University of Texas at Austin
Fiber optic sensing, optical and electronic materials, electro-optic devices and Fourier optics.

Cheng Hsiao Wu, Professor
PHD University of Rochester
Quantum resistor network theory, semiconductor device modeling, DLTS measurement, optical computing.

Donald C Wunsch II, Professor
PHD University of Washington
Adaptive critic designs, neural networks, fuzzy systems, nonlinear adaptive control, intelligent agents, applications, financial engineering.

Chengshan Xiao, Professor
PHD University of Sydney-Australia
Wireless communications, information theory, signal processing, and underwater acoustic communications.

Maciej J Zawodniok, Associate Professor
PHD University of Missouri-Rolla
Embedded systems for cyber infrastructure, wireless sensor and ad hoc networks, and general wireless communications systems.

Yahong Rosa Zheng, Associate Professor
PHD Carleton University
Wireless communication systems, wireless ad hoc/sensor networks, array signal processing, and real time digital signal processing.

Reza Zoughi, Professor
PHD University of Kansas
Electromagnetics, microwave engineering, and microwave and millimeter wave nondestructive evaluation.

**ELEC ENG 5000 Special Problems** (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department. Consent of instructor required.
ELEC ENG 5200 Classical Optics (LEC 3.0)
Physical optics and advanced topics in geometrical optics. Topics include ray propagation, electromagnetic propagation, mirrors, lenses, interference, diffraction, polarization, imaging systems, and guided waves. Prerequisites: Math 2222 and Physics 2135 or 2111. (Co-listed with Physics 4503).

ELEC ENG 5210 Fourier Optics (LEC 3.0)
Applications of Fourier analysis and linear systems theory to optics. Topics include scalar diffraction theory, Fourier transforming properties of lenses, optical information processing, and imaging systems. Prerequisites: Both ELEC ENG 3400 and 3600 or both PHYSICS 2401 and 4211. (Co-listed with PHYSICS 5503).

ELEC ENG 5220 Fiber And Integrated Optics (LEC 3.0)
Introduction to optical waveguides and their applications to communication and sensing. Topics include dielectric waveguide theory, optical fiber characteristics, integrated optic circuits, coupled-mode theory, optical communication systems, and photonic sensors. Prerequisite: ELEC Eng 3600 or Physics 4211. (Co-listed with Physics 5513).

ELEC ENG 5250 Optical Computing (LEC 3.0)
Introduction to the principles, subsystems, and architectures of optical computing. Topics include characteristics of optical devices; optical implementations of memory, logic elements, and processors; and computational structures. Prerequisite: Comp Eng 2210 or equivalent. (Co-listed with Comp Eng 5230).

ELEC ENG 5270 Smart Materials And Sensors (LEC 2.0 and LAB 1.0)
Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior standing and Math 3304. (Co-listed with Aero Eng 5529, Mech Eng 5229 and Civ Eng 5118).

ELEC ENG 5300 Digital Control (LEC 3.0)
Analysis and design of digital control systems. Review of z-transforms; root locus and frequency response methods; state space analysis and design techniques; controllability, observability and estimation. Examination of digital control algorithms. Prerequisite: ELEC Eng 3320.

ELEC ENG 5310 Computational Intelligence (LEC 3.0)
Introduction to Computational Intelligence (CI), Biological and Artificial Neuron, Neural Networks, Evolutionary Computing, Swarm Intelligence, Artificial Immune Systems, Fuzzy Systems, and Hybrid Systems. CI application case studies covered include digital systems, control, power systems, forecasting, and time-series predictions. Prerequisite: Graduate Standing. (Co-listed with Comp Eng 5310 and Sys Eng 5211).

ELEC ENG 5320 Neural Networks Control and Applications (LEC 3.0)
Introduction to artificial neural networks and various supervised and unsupervised learning techniques. Detailed analysis of some of the neural networks that are used in control and identification of dynamical systems. Applications of neural networks in the area of Control. Case studies and a term project. Prerequisites: ELEC Eng 3320.

ELEC ENG 5330 Fuzzy Logic Control (LEC 3.0)
A mathematical introduction to the analysis, synthesis, and design of control systems using fuzzy sets and fuzzy logic. A study of the fundamentals of fuzzy sets, operations on these sets, and their geometrical interpretations. Methodologies to design fuzzy models and feedback controllers for dynamical systems. Various applications and case studies. Prerequisite: ELEC Eng 3320.

ELEC ENG 5340 Advanced PLC (LEC 2.0 and LAB 1.0)
Advanced programmable logic controller (PLC) programming, function block, structured text, function chart, sequencer. Factory communications, system simulation, human-machine interface (HMI) programming. Advanced PID control. Network security and reliability. Class-wide project. Prerequisite: ELEC Eng 3340.

ELEC ENG 5350 Plantwide Process Control (LEC 3.0)
Synthesis of control schemes for continuous and batch chemical plants from concept to implementation. Multiloop control, RGA, SVD, constraint control, multivariable model predictive control, control sequence descriptions. Design project involving a moderately complicated multivariable control problem. Prerequisites: CHEM Eng 4110 or ELCE Eng 3320 or ELCE Eng 3340 or graduate standing. (Co-listed with CHEM Eng 5190).

ELEC ENG 5360 System Simulation And Identification (LEC 3.0)

ELEC ENG 5370 Introduction to Neural Networks and Applications (LEC 3.0)
The course provides an introduction to basic neural network architectures and their applications. Students learn to construct neural networks and train them to solve engineering problems, specifically pattern recognition and function approximation. Mathematical analysis of network architectures, training algorithms and practical applications of neural nets. Prerequisites: Graduate Standing. (Co-listed with Sys Eng 5212).

ELEC ENG 5380 Autonomous Mobile Robots (LEC 3.0)
This course will provide an introduction to mobile robots and current approaches to robot autonomy. Topics include mobile robot systems, modeling and control, sensors and estimation, localization and mapping, and motion planning. Prerequisites: ELEC Eng 3320 or equivalent and Stat 3117 or equivalent.

ELEC ENG 5400 Digital Signal Processing II (LEC 3.0)
Spectral representations, sampling, quantization, z-transforms, digital filters and discrete transforms including the Fast Fourier transform. Prerequisites: ELEC Eng 3410 or ELEC Eng 3420.

ELEC ENG 5420 Communications Systems II (LEC 3.0)
Random signals and their characterization; noise performance of amplitude, angle and pulse modulation systems; digital data transmission; use of coding for error control. Prerequisite: ELEC Eng 3420.
**ELEC ENG 5430 Wireless Networks** (LAB 1.0 and LEC 2.0)  
Introduction to wireless communications and networking. Topics include transmission fundamentals, wireless channel, coding techniques and error control, satellite and cellular networks, cordless systems, mobile IP and management, multiple access techniques and wireless protocols, wireless LAN, IEEE 802.11, and adhoc and sensor networks. Prerequisites: Hardware competency, Elec Eng 3420 or Comp Eng 3150 and graduate standing. (Co-listed with Comp Eng 5430 and Sys Eng 5323).

**ELEC ENG 5440 Stochastic Signal Analysis I** (LEC 3.0)  
Introduction to the application of probabilistic models to typical electrical engineering problems. Topics include: methods for describing random voltages, random digital signals, correlation, linear mean-square estimation, linear transformation of random digital signals, and bit-error rate calculation for communication systems. Prerequisites: Math 3304 and Elec Eng 2120.

**ELEC ENG 5450 Digital Image Processing** (LEC 3.0)  
Fundamentals of human perception, sampling and quantization, image transforms, enhancement, restoration, channel and source coding. Prerequisites: At least one of the following: Elec Eng 3400, Elec Eng 3410, Elec Eng 3420, or prior exposure to Fourier Transforms and consent of the instructor. (Co-listed with Comp Eng 5450).

**ELEC ENG 5460 Machine Vision** (LEC 3.0)  
Image information, image filtering, template matching, histogram transformations, edge detection, boundary detection, region growing and pattern recognition. Complementary laboratory exercises are required. Prerequisites: At least one of the following: Elec Eng 3400, Elec Eng 3410, Elec Eng 3420, or prior exposure to Fourier Transforms and consent of the instructor. (Co-listed with Comp Eng 5460).

**ELEC ENG 5500 Electric Drive Systems** (LEC 3.0)  
Course content is roughly 1/3 power electronics, 1/3 applied control and 1/3 electric machinery and focuses on analysis, simulation, and control design of electric drive based speed, torque, and position control systems. Prerequisites: Elec Eng 3500 and Elec Eng 3320.

**ELEC ENG 5510 Electric-Drive Vehicles** (LEC 3.0)  
Course covers introductory topics related to understanding-analysis of electric, hybrid/plug-in hybrid power trains. Classification of hybrid drivetrains, driving cycles, energy storage systems, mechanical coupling devices, automotive applications of fuel cells and introduction to power converters. Prerequisite: Senior standing and Physics 2135.

**ELEC ENG 5520 Power Electronics** (LEC 3.0)  
Analysis, design, modeling, and control of switching mode power converter circuits for ac-dc, dc-dc, dc-ac, and ac-ac conversion. Power semiconductor devices, passive components, and non-ideal sources and loads. Applications to industry, consumer goods, electric vehicles, and alternative energy. Prerequisite: Elec Eng 3100.

**ELEC ENG 5521 Power Electronics Laboratory** (LAB 2.0)  
An introduction to power electronic circuits is presented. Students will construct several dc/dc, dc/ac and ac/dc converters. Various switching algorithms, including pulse width modulation, delta modulation, and hysteresis control will be developed to regulate and control the respective circuits. Prerequisite: Co-requisite Elec Eng 5520.

**ELEC ENG 5540 Power Systems Engineering** (LEC 3.0)  
Network analysis applied to power systems; the load flow concept; economic operation of power systems; synchronous machine reactances and transient stability; symmetrical components and asymmetrical faults; protective relaying. Prerequisite: Elec Eng 3540.

**ELEC ENG 5550 Electric Power Quality** (LEC 3.0)  
Definitions of power quality, types of power quality problems; sources of sags, transient overvoltages and harmonics; distribution overcurrent protection methods and their effect on power quality and reliability; harmonic analysis, principles of controlling harmonics, devices for filtering harmonics; power quality improvement methods. Prerequisite: Elec Eng 3500 or Elec Eng 3540.

**ELEC ENG 5570 Extra High Voltage Engineering** (LEC 2.0 and LAB 1.0)  
The physical phenomena associated with high voltage dielectric breakdown are presented. Methods of generating and measuring high voltages and currents are explained. Demonstration of design and performance. Field trips to companies for laboratory testing of high voltage according to industry standards will serve as the lab part of the course. Prerequisite: Senior standing.

**ELEC ENG 5600 Interference Control in Electronic Systems** (LEC 3.0)  
Principles of high frequency effects in PCBs and components, generation of unwanted radio-frequency (RF) signals by ICs, RF radiation mechanisms, shielding, and immunity against electrostatic discharge and RF signals. Prerequisites: Elec Eng 3400 and 3600.

**ELEC ENG 5620 Signal Integrity in High-Speed Digital & Mixed Signal Design** (LEC 3.0)  
Signal integrity ensures signals transmitted over a propagation path maintain sufficient fidelity for proper receiver operation. Compromised signal integrity is often associated with parasitics (e.g. unintentional inductance, capacitance). Theory and CAD tools used for signal integrity analysis of functioning designs. Prerequisites: Elec Eng 3600 or Comp Eng 3150, and Senior standing. (Co-listed with Comp Eng 5620).

**ELEC ENG 5630 Wave Propagation and Transmission Lines** (LEC 3.0)  
The materials in this course are intended to provide a) follow up electromagnetics related courses, b) electromagnetics related career including RF design and c) a graduate degree in electromagnetic related fields an in-depth understanding of the basics of wave propagation and transmission lines. Prerequisite: Elec Eng 3600.

**ELEC ENG 5640 Antennas and Propagation** (LEC 3.0)  
Propagated fields of elemental dipole, directivity and gain, radiation resistance, the half-wave dipole, wire antennas, arrays, broadband antennas, aperture antennas, horn antennas, and antenna temperature. Prerequisite: Elec Eng 3600.

**ELEC ENG 5650 Microwave and Millimeter Wave Engineering and Design** (LEC 3.0)  
Introduce senior and graduate students to the concept of microwave and millimeter wave engineering and passive component design such as waveguide, cavities, couplers, detectors, mixers, etc., including network theory and scattering matrix. Finally, their specific application in the design of various microwave circuits will be discussed. Prerequisites: Elec Eng 3600.

**ELEC ENG 5660 Microwave Principles For Mixed-Signal Design** (LEC 3.0)  
Transmission lines; coupled transmission lines; microwave network analysis; impedance matching and tuning; design of microwave amplifiers and oscillators. Prerequisite: Elec Eng 3600.

**ELEC ENG 5670 Nondestructive Testing** (LEC 3.0)  
Principles and applications of various means of non-destructive testing of metallic materials. Radiological inspection methods, ultrasonic testing, magnetic methods, electrical and eddy current methods and others. Prerequisite: Physics 2135 or 2111. (Co-listed with Met Eng 5510).
ELEC ENG 5870 Mechatronics (LAB 1.0 and LEC 2.0)
This course will introduce students to the basics of mechatronics (i.e.,
the integration of mechanical, electrical, computer, and control systems).
Students will learn the fundamentals of sensors and actuators for
mechanical systems, computer interfacing, microcontrollers, real-time
software, and control. Prerequisite: Mech Eng 4479 or equivalent. (Co-
listed with Mech Eng 5478, Aero Eng 5478 and Comp Eng 5820).

ELEC ENG 5880 Introduction to Robotics (LEC 3.0)
This course provides an introduction to robotics, covering robot
hardware, fundamental kinematics, trajectories, differential motion,
robotic decision making, and an overview of current topics in robotics.
Prerequisite: A "C" or better in both Math 3108 and Comp Sci 1510. (Co-
listed with Comp Sci 5403 and Comp Eng 5880).

ELEC ENG 6000 Special Problems (IND 0.0-6.0)
Problems or readings on specific subjects or projects in the department.
Consent of instructor required.

ELEC ENG 6001 Special Topics (LAB 0.0 and LEC 0.0)
This course is designed to give the department an opportunity to test a
new course. Variable title.

ELEC ENG 6040 Oral Examination (IND 0.0)
After completion of all other program requirements, oral examinations for
on-campus M.S./Ph.D. students may be processed during intersession.
Off-campus M.S. students must be enrolled in oral examination and
must have paid an oral examination fee at the time of the defense/
comprehensive examination (oral/ written). All other students must enroll
for credit commensurate with uses made of facilities and/or faculties. In
no case shall this be for less than three (3) semester hours for resident
students.

ELEC ENG 6050 Continuous Registration (IND 1.0)
Doctoral candidates who have completed all requirements for the degree
except the dissertation, and are away from the campus must continue
to enroll for at least one hour of credit each registration period until the
degree is completed. Failure to do so may invalidate the candidacy.
Billing will be automatic as will registration upon payment.

ELEC ENG 6085 Internship (IND 0.0-1.5)
Students working toward a doctor of engineering degree will select, with
the advice of their committees, appropriate problems for preparation of a
dissertation. The problem selected and internship plan must conform to
the purpose of providing a high level engineering experience consistent
with the intent of the doctor of engineering degree.

ELEC ENG 6099 Special Research And Thesis (IND 0.0-15)
Investigations of an advanced nature leading to the preparation of a
thesis or dissertation. Consent of instructor required.

ELEC ENG 6140 Advanced RF & Time Domain Measurements (LAB 1.0 and
LEC 2.0)
Advanced measurement techniques and instrumentation: Oscilloscopes
(Real time and sampling, A/D conversion errors, Probing, Jitter, Noise),
Spectrum analyzer (concepts, applications), Network Analyzer (concepts,
calibration), Impedance measurements. Lab experiments are a main part
of this class. Prerequisite: Graduate standing.

ELEC ENG 6150 Signal Integrity, High Speed Digital and RF Design Laboratory
(LAB 3.0)
This is an RF and digital electronics design class. Student groups will
design, manufacture and test RF and/or digital circuits during the class.
Besides this project work the lecture part will emphasize circuit design,
layout, parasitic effects and design for testability. Prerequisite: Elec Eng
3600.

ELEC ENG 6200 Electromagnetic Optics (LEC 3.0)
Propagation, control, and modulation of laser radiation. Topics include
optical polarization, interference, layered and anisotropic media, electro-
optic devices, acousto-optic devices, and nonlinear optics. Prerequisite:
Elec Eng 3600 or Physics 4211.

ELEC ENG 6240 Semiconductor Devices (LEC 3.0)
Properties of semiconductors, junctions and transistors; high frequency
and high-current effects; recombination processes; field-effect devices,
semiconductor devices and microcircuits. Prerequisite: Graduate status
in Elec Eng.

ELEC ENG 6260 Integrated Microsystems Engineering (LEC 1.5 and LAB 1.5)
Theory and practice of multidisciplinary integrated microsystem
technologies. The topics include (1) micromachining technology,
(2) review of mechanical, optical, microfluidic and (bio) chemical
macrosensors and microactuators, (3) hands-on lab session for design,
fabrication, and characterization of Microsystems. Prerequisite: Graduate
standing.

ELEC ENG 6290 Advanced Topics in Optics and Devices (LEC 3.0)
Advanced topics of current interest in optics and devices. Selected
topics include semiconductor materials, electronic devices, wave-based
sensing, fiber optic systems, optoelectronics, and photonic engineering.
Prerequisite: Graduate Standing.

ELEC ENG 6300 Linear Control Systems (LEC 3.0)
Review of linear algebra, state variable formulations, solutions of state
equations; controllability and observability; multivariable systems, matrix-
fraction decompositions; design of state and output feedback controllers
and observers; introduction to calculus of variations; linear quadratic
regulators. Prerequisite: Elec Eng 3320.

ELEC ENG 6310 Optimal Control And Estimation (LEC 3.0)
Review of linear quadratic regulators (LQR), LQR extensions; constrained
optimization (Pontragin's minimum principle); review of probability
theory and random processes; optimal prediction and filters; frequency
domain properties of LQR and Kalman filters; linear quadratic Gaussian
(LQG) control; model uncertainties, frequency shaping; LQG/LTR design
methodology. Prerequisite: Elec Eng 6300.

ELEC ENG 6320 Nonlinear Control Systems (LEC 3.0)
Numerical solution methods, describing function analysis, direct and
indirect methods of Liapunov stability, applications to the Lure problem
- Popov circle criterion. Applications to system design and feedback
linearizations. Prerequisite: Elec Eng 6300.

ELEC ENG 6330 Robust Control Systems (LEC 3.0)
Performance and robustness of multivariable systems, linear
fractional transformations, LQG/LTR advanced loop shaping, Youla
parameterization, H (subscript infinity) optimal control, mixed H
(subscript 2) and H (subscript infinity) control, controller synthesis for
multiple objective optimal control, linear matrix inequalities theory and
case studies. Prerequisite: Elec Eng 6300.

ELEC ENG 6335 Discrete-Time Neural Network Control (LEC 3.0)
Neural network topologies, universal function approximation property,
background on Lyapunov stability & dynamic systems, control of a
class of nonlinear systems using single and multilayer neural networks,
feedback linearization, strict & nonstrict feedback systems, MIMO
system, system identification, output feedback control, and hardware
implementation. Prerequisites: Elec Eng 6300.
ELEC ENG 6340 Clustering Algorithms (LEC 3.0)
An introduction to cluster analysis and clustering algorithms rooted in computational intelligence, computer science and statistics. Clustering in sequential data, massive data and high dimensional data. Students will be evaluated by individual or group research projects and research presentations. Prerequisite: At least one graduate course in statistics, data mining, algorithms, computational intelligence, or neural networks, consistent with student’s degree program. (Co-listed with Comp Eng 6330, Sys Eng 6214, Comp Sci 6405 and Stat 6239).

ELEC ENG 6350 Neural Network Control of Nonlinear Continuous-time Systems (LEC 3.0)
Neural network topologies, universal function approximation property, background on Lyapunov stability and dynamic systems, control of a class of nonlinear systems and robot manipulators, feedback linearization, backstepping control, force control, neural observers, decentralized neural network control, neural network-based optimal control and applications. Prerequisite: Elec Eng 6300.

ELEC ENG 6360 Adaptive Dynamic Programming (LEC 3.0)
Review of Neurocontrol and Optimization, Introduction to Approximate Dynamic Programming (ADP), Reinforcement Learning (RL), Combined Concepts of ADP and RL - Heuristic Dynamic Programming (HDP), Dual Heuristic Programming (DHP), Global Dual Heuristic Programming (GDHP), and Case Studies. Prerequisites: Elec Eng 5370 or Comp Eng 5310. (Co-listed with Comp Eng 6320, Mech Eng 6458, Aero Eng 6458 and Sys Eng 6215).

ELEC ENG 6390 Current Topics In Control Theory (LEC 3.0)
Topics of current interest in control theory literature. Offered as interest and demand warrant. Prerequisite: Consent of instructor.

ELEC ENG 6400 Advanced Digital Signal Processing (LEC 3.0)
Continuation of Elec Eng 5400. Effects of discrete noise sources in digital signal processing; discrete spectral analysis of random signals; discrete time signal detection, estimation, and filtering algorithms. Prerequisites: Elec Eng 5400 or Elec Eng 5420; Elec Eng 5440 or Stat 5643.

ELEC ENG 6410 Information Theory And Coding (LEC 3.0)
Principles of information generation, transmission and processing, quantitative measure of information, entropy source encoding; channels; mutual information; channel capacity; Shannon’s second theorem for discrete channels; introduction to coding for error controls; continuous information sources. Prerequisites: Elec Eng 5420 or Elec Eng 5440 or Stat 5643.

ELEC ENG 6420 Wireless Communications (LEC 3.0)
Introduction to the principle of wireless communication systems. Topics include: wireless channel characteristics, cellular concepts, channel capacity analysis, transceiver architectures, diversity techniques, multiple access schemes, and practical wireless systems. Prerequisite: Elec Eng 5420 or Elec Eng 5440 or equivalent.

ELEC ENG 6430 Wireless Ad hoc and Sensor Networks (LEC 3.0)
Introduction to ad hoc and sensor networks, IEEE standards, heterogeneity, quality of service, wireless channel issues, energy awareness, power and topology control, routing, scheduling, rate adaptation, self-organization, admission and flow control, energy harvesting, security and trust levels, hardware and applications. Prerequisite: Comp Eng 5430 or Comp Eng 5420 or equivalent. (Co-listed with Comp Eng 6420 and Sys Eng 6324).

ELEC ENG 6440 Stochastic Signal Analysis II (LEC 3.0)
Continuous-time stochastic signals, multi-dimensional signals, Wiener and matched filters, LMS equalization, non-linear systems with random inputs, spectral estimation and Markov chains. Prerequisites: Stat 5643 or Elec Eng 5440.

ELEC ENG 6450 Statistical Decision Theory (LEC 3.0)
Classical detection and estimation theory with applications; hypothesis testing, detection of known signals, matched filter receiver implementation, detection of signals with unknown parameters, sequential and nonparametric detection, detection of stochastic signals: Parameter estimation theory with application to modulation. Prerequisite: Elec Eng 5440.

ELEC ENG 6490 Advanced Topics In Communications (LEC 3.0)
Advanced topics of current interest in communications and signal processing such as spread spectrum, digital processing of communications, speech, and radar signals, applications of pattern recognition, communications networks, specialized coding topics. Repeatable for additional credit toward degree each time a different subtitle offered. Prerequisite: Elec Eng 5420 or 5440.

ELEC ENG 6500 Advanced Theory Of Electric Machines (LEC 3.0)
Energy conversion, reference frame theory, transient and dynamic modeling of ac machines, simulation of ac machines, parameter identification, model-order reduction, advanced topics depending on semester taught. Prerequisite: Elec Eng 3500.

ELEC ENG 6510 Advanced Electric Drive Vehicles (LEC 3.0)
This course covers an entire range of advanced topics related to the analysis, design, control, simulation, and optimization of electric, hybrid, and plug-in hybrid power-trains including the automotive applications of adjustable speed motor drives, energy storage systems, and advanced power converters. Prerequisite: Elec Eng 5500 or Elec Eng 5520.

ELEC ENG 6520 Advanced Power Electronics (LEC 3.0)
The purpose of this course is to cover selected areas of power electronics in greater depth. The topics covered include small signal analysis of power converters, voltage- and current- mode control, soft switching techniques, power factor connectors, multi-level converters, and PWM techniques. Prerequisite: Elec Eng 5520.

ELEC ENG 6525 Power Converter Modeling and Design (LEC 3.0)
Students will integrate electrical, magnetic, and thermal modeling techniques into a design process for switching power converters. A variety of applications will be considered, including dc-dc, ac-dc, and dc-ac converters over a wide power range. Prerequisite: Elec Eng 5520.

ELEC ENG 6530 Power System Reliability (LEC 3.0)

ELEC ENG 6540 Computer Methods In Power System Analysis (LEC 3.0)
Algorithms for large scale system solution, non-linear systems, ordinary differential equations, eigenvalue problems, modal information, and optimization. Applications to power systems analysis. Prerequisite: Elec Eng 3540 or similar course.

ELEC ENG 6550 Power System Stability (LEC 3.0)
Synchronous machine theory and modelling; AC transmission; power system loads; excitation systems; control of active and reactive power; small signal stability; transient stability; voltage stability, mid-term and long-term stability; subsynchronous oscillations; stability improvement. Prerequisite: Elec Eng 3540 or similar course.
**ELEC ENG 6560 Power System Protection** (LEC 3.0)
Protective relaying incorporating electromechanical, solid state and computer relaying methods for high voltage transmission systems; instrument transformers; generator, transformer, line and bus protection; effect of system grounding; pilot protection and out of step relaying principles. Prerequisite: Elec Eng 5560 and 5540.

**ELEC ENG 6570 Surge Phenomena In Power Systems** (LEC 3.0)
Study of transmission system insulation, distributed constant lines, terminations, multiple reflections, lighting performance, characteristics of sustained and switching overvoltages, surge voltages due to system faults, energizing and reclosing of circuit breakers. Methods of reducing overvoltages to acceptable levels. Prerequisite: Elec Eng 5540.

**ELEC ENG 6580 Power System Operations** (LEC 3.0)
Optimal dispatch operations, economic loading of power plants, mathematical optimization, locational marginal pricing, optimal power flow; effect of hydro and wind power plants on system economics; contingency analysis and system security, state estimation. Prerequisite: Elec Eng 5540.

**ELEC ENG 6600 Advanced Electromagnetics I** (LEC 3.0)
Review of Maxwell’s equations, constitutive relations, and boundary conditions. Wave propagation and polarization. Vector magnetic and electric potentials. Equivalent representations of fields, Babinet’s principle. Circular waveguides. Green’s functions. Prerequisite: Elec Eng 3600 or equivalent undergraduate electromagnetics course.

**ELEC ENG 6610 Electromagnetic Waves II** (LEC 3.0)
Circular waveguides, circular cavities, scattering by cylinders, apertures in cylinders, spherical cavities, orthogonality relationships, source of spherical waves, scattering by spheres, perturbational and variational techniques, microwave networks, probes in cavities, and aperture coupling to cavities. Prerequisite: Elec Eng 6600.

**ELEC ENG 6630 Computational Electromagnetics** (LEC 3.0)
Differential-equation based numerical methods-finite element, finite-difference, and finite-difference time-domain—for solving static and dynamic equations of electromagnetics. Applications considered are multi-conductor transmission lines, Maxwell’s equations for radiation and scattering, and electric machinery. Prerequisite: Elec Eng 3600.

**ELEC ENG 6640 Advanced Topics in Antenna Analysis and Design** (LEC 3.0)
Introduction and discussion of advanced antenna design issues including: polarization, antenna synthesis and source modeling, broadband antennas, aperture and microstrip antenna simulation and design, and antenna pattern measurement techniques including near-field to far-field transformation. Prerequisite: Elec Eng 5640 or equivalent.

**ELEC ENG 6690 Topics in EMC and High Speed Digital Design** (LEC 3.0)
This course will cover advanced topics in electromagnetic compatibility and high speed digital design that are not traditionally covered in other courses. Topics will depend on the latest developments in the field and on student needs. Prerequisite: Elec Eng 3600.

**ELEC ENG 6810 Philosophy of Scientific Research** (LEC 3.0)
Organization and planning of research. Introduction to the philosophy and management of scientific research, particularly issues related to ethics, plagiarism, ownership of intellectual properties, research techniques, technical presentations and time management. The course will address these issues by integrating with case studies. (Co-listed with Chem Eng 6340, IDE 425, Civ Eng 6940, Env Eng 6940, Comp Eng 6810).