ELECTRICAL ENGINEERING (EE)

Courses primarily for undergraduates:

EE 1660: Professional Programs Orientation
(Cross-listed with CPRE 1660).
Credits: Required. Contact Hours: Lecture 1.
(1-0) Overview of the nature and scope of electrical engineering and computer engineering professions. Overview of portfolios. Departmental rules, advising center operations, degree requirements, program of study planning, career options, and student organizations. Offered on a satisfactory-fail basis only. (Typically Offered: Fall, Spring)

EE 1850: Introduction to Electrical Engineering and Problem-Solving I
Credits: 3. Contact Hours: Lecture 2, Laboratory 2.
Prereq: MATH 1430 *or satisfactory scores on mathematics placement examinations; credit or enrollment in* MATH 1650
Project based examples from electrical engineering. Systematic thinking process for engineering problem solving. Group problem solving. Mathematical, conceptual and computer-based projects. Solving engineering problems and presenting solutions through technical reports and oral presentations. Solutions of engineering problems using computation tools and basic programming. Satisfactory placement scores can be found at: https://math.iastate.edu/academics/undergraduate/aleks/placement/.Graduation Restriction: Only one of ENGR 1600, ABE 1600, AERE 1600, BME 1600, CE 1600, CHE 1600, CPRE 1850, EE 1850, IE 1480, ME 1600, and SE 1850 may count towards graduation. (Typically Offered: Fall, Spring)

EE 1860: Introduction to Electrical Engineering and Problem Solving II
Credits: 1.
Prereq: EE 1850
Project based and hands on continuation of 1850. Group skills needed to work effectively in teams. Individual interactive skills for small and large groups. Learning to use tools and methods for solving electrical engineering problems. (Typically Offered: Spring)

EE 2010: Electric Circuits
Credits: 4. Contact Hours: Lecture 3, Laboratory 2.
Prereq: PHYS 2310 *or* PHYS 2310H*;* PHYS 2310L*; credit or concurrent enrollment in* MATH 2670
Emphasis on mathematical tools. Circuit elements (resistors, inductors, capacitors) and analysis methods including power and energy relationships. Network theorems. DC, sinusoidal steady-state, and transient analysis. AC power. Frequency response. Two port models. Diodes, PSPICE. Laboratory instrumentation and experimentation. Graduation Restriction: Credit for only EE 2010 or 4420 may be used towards graduation. (Typically Offered: Fall, Spring)

EE 2240: Signals and Systems I
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 2010*;* MATH 2670
Mathematical preliminaries. Introduction to signals and systems. Signal manipulations. System properties. LTI systems, impulse response and convolution. Fourier Series representation and properties. Continuous and discrete-time Fourier Transforms and properties. Sampling and reconstruction. Modulation and demodulation. Applications and demonstrations using Matlab. (Typically Offered: Fall, Spring)

EE 2300: Electronic Circuits and Systems
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 2010*;* MATH 2670
Frequency domain characterization of electronic circuits and systems, transfer functions, sinusoidal steady state response. Time domain models of linear and nonlinear electronic circuits, linearization, small signal analysis. Stability and feedback circuits. Operational amplifiers, device models, linear and nonlinear applications, transfer function realizations. A/D and D/A converters, sources of distortions, converter linearity and spectral characterization, applications. Design and laboratory instrumentation and measurements. (Typically Offered: Fall, Spring)

EE 2320: Professional and Ethical Issues in Electrical and Computer Engineering
(Cross-listed with CPRE 2320).
Credits: 3. Contact Hours: Lecture 3.
Prereq: COMS 2270 *or EE 2850*
Professional and ethical issues in electrical and computer engineering. Soft skills, including communication and leadership skills, and how they relate to the engineering profession. Case studies illustrating ethical decision making in an engineering context and differentiating between moral and professional ethics. Issues of diversity, equity, and inclusion in the engineering profession.

EE 2610: Transfer Orientation
(Cross-listed with CPRE 2610).
Credits: Required. Contact Hours: Lecture 1.
Introduction to the College of Engineering and the engineering profession specifically for transfer students. Information concerning university and college policies, procedures, and resources. Offered on a satisfactory-fail basis only.

EE 2850: Problem Solving Methods and Tools for Electrical Engineering
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Integration of field-specific computational tools for practically solving electrical engineering problems. Methods for systematically reducing problems into sequential steps compatible with computer based tools. Structuring computer programs for efficiency and maintainability. Integration of multi-platform operating systems and multi-vendor tools for solving engineering problems. Hands-on laboratory experiences using Matlab, C, and other computational tools.

EE 2940: Program Discovery
(Cross-listed with CPRE 2940).
Credits: Required. Contact Hours: Lecture 1.
Prereq: CPRE 1660 *or EE 1660*
The roles of professionals in computer and electrical engineering. Relationship of coursework to industry and academic careers. Issues relevant to today's world. Offered on a satisfactory-fail basis only.

EE 3030: Energy Systems and Power Electronics
Credits: 3. Contact Hours: Lecture 3.
Prereq: MATH 2670*;* PHYS 2320 *or* PHYS 2320H*; credit or concurrent enrollment in EE 2300*
Structure of competitive electric energy systems. System operation and economic optimization. Mutual inductance, transformers. Synchronous generators. Balanced three-phase circuit analysis and power calculations. Network calculations and associated numerical algorithms. Two-port circuits. Voltage regulation. Resonance and power factor correction. DC and induction motors. Power electronic circuit applications to power supplies and motor drives. (Typically Offered: Fall, Spring)

EE 3110: Electromagnetic Fields and Waves
Credits: 4. Contact Hours: Lecture 4.
Prereq: EE 2010*,* MATH 2650*,* PHYS 2320*,* PHYS 2320L *and Credit or concurrent enrollment in* MATH 2670
Fundamentals and applications of electric and magnetic fields and materials. Electrostatics and magentostatics, potentials, capacitance and inductance, energy, force, torque. Uniform plane electromagnetic waves, Poynting vector. Transmission lines: transient and sinusoidal steady-state conditions, reflection coefficient. (Typically Offered: Fall, Spring)

EE 3140: Electromagnetics for non Electrical Engineers
Credits: 3. Contact Hours: Lecture 3.
Prereq: PHYS 2320
Conceptual study of electomagnetism and its application in engineering and related fields. EM fundamentals, EM spectrum, radiation, radiating systems, wireless, modern concepts of physics, quantum computing, transmission lines, high speed effects, waveguides, GPS and other related phenomena will be discussed and explained with the application in mind. (Typically Offered: Fall, Spring)

EE 3210: Communication Systems I
Credits: 3. Contact Hours: Lecture 3.
Frequency domain analysis, spectral filtering, bandwidth. Linear modulation systems. Angle modulation systems. Phase locked loop, super-heterodyne receiver. Sampling and pulse code modulation. Digital data transmission, line coding, pulse shaping, multiplexing. (Typically Offered: Fall)

EE 3220: Probabilistic Methods for Electrical Engineers
(Cross-listed with STAT 3220).
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 2240
Introduction to probability with applications to electrical engineering. Sets and events, probability space, conditional probability, total probability and Bayes' rule. Discrete and continuous random variables, cumulative distribution function, probability mass and density functions, expectation, moments, moment generating functions, multiple random variables, functions of random variables. Elements of statistics, hypothesis testing, confidence intervals, least squares. Introduction to random processes. (Typically Offered: Fall, Spring)

EE 3240: Signals and Systems II
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 2240
Laplace and z-Transforms, properties and inverses. Applications to LTI systems, circuits, analog/digital filters, feedback systems, stability analysis and margins. MATLAB labwork covering these topics. (Typically Offered: Fall, Spring)

EE 3300: Integrated Electronics
(Cross-listed with CPRE 3300).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: CPRE 2810*;* EE 2010*; credit or concurrent enrollment in EE 2300*
Semiconductor technology for integrated circuits. Modeling of integrated devices including diodes, BJTs, and MOSFETs. Physical layout. Circuit simulation. Digital building blocks and digital circuit synthesis. Analysis and design of analog building blocks. Laboratory exercises and design projects with CAD tools and standard cells.

EE 3320: Semiconductor Materials and Devices
(Cross-listed with MATE 3320).
Credits: 3. Contact Hours: Lecture 3.
Prereq: CPRE and EE majors: EE 2300*, MATE majors:* MATE 3170
Introduction to semiconductor material and device physics. Quantum mechanics and band theory of semiconductors. Charge carrier distributions, generation/recombination, transport properties. Physical and electrical properties and fabrication of semiconductor devices such as MOSFETs, bipolar transistors, laser diodes and LED's. (Typically Offered: Spring)

EE 3330: Electronic Systems Design
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: CPRE 2810, EE 2300
Further topics in electronic systems design: Use of sensors and actuators. High-power amplifying and switching components. Linear and switched-mode power supplies. Linear and switched-mode amplifiers. Interfacing electronic components with programmable microcontrollers. Printed circuit board technology and design tools. Laboratory exercises and design projects incorporating printed circuit technology. (Typically Offered: Fall)

EE 3410: BioMEMs and Nanotechnology
(Cross-listed with BME 3410).
Credits: 3. Contact Hours: Lecture 3.
Prereq: BME 2200
Overview of Micro-Electro-Mechanical-System (MEMS) technologies for bioengineering, fundamentals of microfluidic device design, fabrication, and characterization, survey of microfluidic functional building blocks for lab-on-a-chip applications including mixers, valves, channels, and chambers. Topics of nanotechnology in bioengineering, nanoscale building block technologies for bioengineering including self-assembling, surface chemical treatment, nano-imprinting, nano-particles, nano-tubes, nano-wires, and stimuli-responsive biomaterials.

EE 3510: Analysis of Energy Systems
Credits: 3. Contact Hours: Lecture 3.
Energy-scientific, engineering and economic foundations. Energy utilization-global and national. Sectoral analysis of energy consumption. Relationship of energy consumption and production to economic growth and environment. Technology for energy production. Economic evaluation of energy utilization and production. Scientific basis for global warming. Environmental impact of energy production and utilization. Renewable energy. Meets International Perspectives Requirement.

EE 3880: Sustainable Engineering and International Development
(Cross-listed with ABE 3880/ CE 3880).
Credits: 3. Contact Hours: Lecture 2, Laboratory 2.
Prereq: Junior Classification in an Engineering Major
Multi-disciplinary approach to sustainable engineering and international development, sustainable development, appropriate design and engineering, feasibility analysis, international aid, business development, philosophy and politics of technology, and ethics in engineering. Engineering-based projects from problem formulation through implementation. Interactions with partner community organizations or international partners such as nongovernment organizations (NGOs). Course readings, final project/design report. Meets International Perspectives Requirement. (Typically Offered: Fall)

EE 3910: Open Laboratory and Design Studio
Credits: 2.
Prereq: EE 2240
Studio-based activity (guided problem-based learning and design) focusing on elements of design, measurement, data capture, and data interpretation. Team building, engineering professionalism, engineering process of review and critique, and presentation. Open design activities that may include working with other studios.

EE 3940: Program Exploration
(Cross-listed with CPRE 3940).
Credits: Required. Contact Hours: Lecture 1.
Prereq: CPRE 2940 *or EE 2940*
Exploration of academic and career fields for electrical and computer engineers. Examination of professionalism in the context of engineering and technology with competencies based skills. Introduction to professional portfolio development and construction. Offered on a satisfactory-fail basis only.

EE 4110: Wave Propagation and Transmission Lines
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3110
Time varying Maxwell's equations; wave equation in an unbounded generally lossy (multi-layered) media; uniform plane waves, dielectric constant, propagation, attenuation and phase constants; wave impedance; phase and group velocities; wave polarization; reflection and transmission coefficients (at oblique incidence) at boundaries (conducting and dielectric); Doppler effect; transmission lines; propagation, attenuation, phase constants; phase velocity; characteristic impedance; load impedance and its influence; reflection and transmission coefficients; cascaded transmission lines; steady-state voltage and current; standing waves; SWR; Smith chart; matching techniques including, quarter-wave matching, single and double stub matching. (Typically Offered: Spring)

EE 4140: Microwave Engineering
(Dual-listed with EE 5140).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 2300, EE 3110
Principles, analyses, and instrumentation used in the microwave portion of the electromagnetic spectrum. Wave theory in relation to circuit parameters. S parameters, couplers, discontinuities, and microwave device equivalent circuits. RF amplifier design, microwave sources, optimum noise figure and maximum power designs. Microwave filters and oscillators. (Typically Offered: Fall)

EE 4170: Electromagnetic Radiation, Antennas, and Propagation
(Dual-listed with EE 5170).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 3110
Fundamental antenna concepts. Radiation from wire-and aperture-type sources. Radio transmission formulas. Wave and antenna polarization. Antenna arrays. Modern antenna topics. Practical antenna design. Antenna noise. Radiowave propagation in the presence of the earth and its atmosphere. Antenna measurements and computer aided analysis. (Typically Offered: Spring)

EE 4180: High Speed System Engineering Measurement and Testing
(Cross-listed with CPRE 4180).
Credits: 4. Contact Hours: Lecture 3, Laboratory 2.
Prereq: EE 2300*,* EE 3110
Measurement of high speed systems and mixed signal systems. Measurement accuracy and error. Network analysis and spectrum analysis used in high speed measurement and testing. Test specification process and parametric measurement. Sampling and digital signal processing concepts. Design for testability. Testing equipment. Applications. (Typically Offered: Fall)

EE 4190: Magnetism and Magnetic Materials
(Dual-listed with MSE 5190/ EE 5190). (Cross-listed with MATE 4190).
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3110 *or* MATE 3170 *or* PHYS 3640
Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenome. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, magnetic measurements of properties for materials evaluation. Offered odd-numbered years. (Typically Offered: Fall)

EE 4220: Communication Systems II
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3210, EE 3220 and Credit or concurrent enrollment in EE 4230
Introduction to probability and random processes; Performance of analog systems with noise; Performance of digital communication with noise; optimum receivers, transmission impairments, and error rates; Introduction to information theory and coding: source coding, channel coding, channel capacity.

EE 4230: Communication Systems Laboratory
Credits: 1. Contact Hours: Laboratory 3.
Prereq: EE 3210 and Credit or concurrent enrollment in EE 4220
Construction and evaluation of modulators, demodulators and other components for analog and digital communications. Design, simulate,and evaluate wireless communication systems and their key components. Noise measurement.

EE 4240: Introduction to Digital Signal Processing
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 2240
Sampling and reconstruction. Concepts and mathematical tools in discrete-time signal and image processing with examples from communications, nondestructive evaluation (NDE), and medical imaging. Discrete-time correlation and matched-filter receivers. Discrete Fourier transform (DFT) and its fast implementation (FFT). 2-dimensional versions. Z transforms. Filter design. Realizations of discrete-time systems and quantization effects. Laboratory experiments illustrating DSP implementations and applications.

EE 4250: Machine learning: A Signal Processing Perspective
Credits: 3. Contact Hours: Lecture 2, Discussion 1.
Prereq: EE 3220/STAT 3220 *or* STAT 3300*; and* MATH 2070 *or* MATH 4070*/5070*
Background material review (probability, calculus, linear algebra), Key machine learning tools and techniques. Supervised Learning: Linear Regression, Logistic Regression, Generative algorithms for classification (Gaussian & discrete-valued case; Naive Bayes assumption), Support Vector Machines, Decision trees; Unsupervised Learning: principal components analysis (PCA), robust PCA, clustering; Introduction to Deep Learning and Neural Networks; Basic Learning Theory and Bias-Variance Tradeoff; introduction to key Bayesian estimation concepts (MMSE estimation, Kalman filter, hidden Markov models). (Typically Offered: Spring)

EE 4280X: Image Analysis using Machine Learning
Credits: 3. Contact Hours: Laboratory 2, Lecture 2.
Repeatable.
Visual recognition tasks such as image classification, localization and detection are core to applications in image understanding. Developments in neural network (aka 'deep learning') approaches have advanced the performance of these state-of-the-art visual recognition systems. Explore deep learning architectures with a focus on learning end-to-end models for tasks such as image classification. Implement, train and debug neural networks and gain a detailed understanding of research in computer vision. Image recognition problem set-up, the learning algorithms (e.g. backpropagation), practical engineering tricks for training and fine-tuning the networks. Final course project. (Typically Offered: Fall)

EE 4320: Microelectronics Fabrication Techniques
(Dual-listed with EE 5320/ MSE 5320). (Cross-listed with MATE 4320).
Credits: 4. Contact Hours: Lecture 2, Laboratory 4.
Prereq: CPRE and EE majors: EE 2300*, MATE majors:* MATE 3170
Techniques used in modern integrated circuit fabrication, including diffusion, oxidation, ion implantation, lithography, evaporation, sputtering, chemical-vapor deposition, and etching. Process integration. Process evaluation and final device testing. Extensive laboratory exercises utilizing fabrication methods to build electronic devices. Use of computer simulation tools for predicting processing outcomes. Recent advances in processing CMOS ICs and micro-electro-mechanical systems (MEMS).

EE 4350: Analog VLSI Circuit Design
(Cross-listed with CPRE 4350).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 3300
Basic analog integrated circuit and system design including design space exploration, performance enhancement strategies, operational amplifiers, references, integrated filters, and data converters. (Typically Offered: Spring)

EE 4360: Physics of Transistors
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3320
Use of energy band diagrams to describe the behavior of junction devices, electron and hole currents in transistors, junction capacitance, parasitic and second-order effects, development of circuit models from the underlying physical behavior, heterojunction devices, high-speed and high-power applications, measurement techniques. (Typically Offered: Spring)

EE 4370: Electronic Properties of Materials
(Dual-listed with EE 5370/ MSE 5370). (Cross-listed with MATE 4370).
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3320 *or* MATE 3170 *or* PHYS 3220
Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenomena. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, biomedical applications of magnetism, magnetic evaluation of materials. (Typically Offered: Spring)

EE 4380: Optoelectronic Devices and Applications
(Dual-listed with EE 5380).
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3110 *and* EE 3320
Transmission and reflection of electromagnetic plane waves. Propagation in dielectric and fiber optic waveguides. LED and laser operating principles and applications. Photodetectors and solar cells. Optical modulation and switching.

EE 4390: Nanoelectronics
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3320 *or* MATE 3340
Concepts of quantum mechanics relevant to nanoelectronic devices, including quantization, tunneling, and transport; overview of some of the leading technologies for nanoelectronics, including carbon nanotubes, quantum dots, and molecular transistors; fabrication methods for building nanoelectronic devices. (Typically Offered: Spring)

EE 4420: Introduction to Circuits and Instruments
Credits: 2. Contact Hours: Lecture 1.5, Laboratory 1.
Prereq: MATH 2670*;* PHYS 2320*;* PHYS 2320L
Half-semester course. Basic circuit analysis using network theorems with time domain and Laplace transform techniques for resistive, resistive-inductive, resistive-capacitive, and resistive- inductive-capacitive circuits. Transient circuit behavior. Basic operational amplifiers and applications. Familiarization with common EE instrumentation and demonstration of basic principles. Graduation Restriction: Credit for only 2010 or 4420 may be counted toward graduation; credit FOR 4420 will not count toward graduation for EE or CPRE majors. (Typically Offered: Fall, Spring)

EE 4480: Introduction to AC Circuits and Motors
Credits: 2. Contact Hours: Lecture 1.5, Laboratory 1.
Prereq: Credit or enrollment in EE 4420
Half-semester course. Basics of DC machines, stepper motors, AC induction motors, and synchronous generators. AC steady state analysis, transformers, and three-phase circuit analysis. (Typically Offered: Fall, Spring)

EE 4500: Biosensors
(Cross-listed with BME 4500).
Credits: 3. Contact Hours: Lecture 3.
Prereq: BME 2200
Overview of biosensors and bioanalytical challenges; designing for performance including various analytical problems, ion-selective membranes, characteristics of enzymes and basics of bioaffinity sensing; fundamentals of bioselective layers including depositing films and membranes, surfaces for immobilization and bioselective agents; survey of different biosensing technologies including electroanalytical, biomembrane, optical, and acoustic-wave based sensors.

EE 4500L: Biosensors Laboratory
(Cross-listed with BME 4500L).
Credits: 1. Contact Hours: Laboratory 3.
Prereq: BME 2200*; concurrent enrollment in* BME 4500 *or EE 4500*
Laboratory course accompanying BME 4500. Design, fabrication, and characterization of various electrical, chemical, polymer, optical and acoustic sensors.

EE 4510: Engineering Acoustics
(Cross-listed with EM 4510/ ME 4510).
Credits: 3. Contact Hours: Lecture 3.
Prereq: MATH 2660 or MATH 2670; PHYS 2310 and 2310L
The basics of acoustic wave propagation in fluids with an emphasis on sound propagation in air. Topics include transmission and reflection of sound at a boundary; role of acoustic sources in directing sound fields; diffraction of sound around solid objects; reverberation of sound in a room; and the measurement of sound fields. (Typically Offered: Fall)

EE 4520: Electrical Machines and Power Electronic Drives
Credits: 3. Contact Hours: Lecture 2, Laboratory 3.
Prereq: EE 3030*,* EE 3240
Basic concepts of electromagnetic energy conversion. DC motors and three-phase induction motors. Basic introduction to power electronics. Adjustable speed drives used for control of DC, induction, and AC motors. Experiments with converter topologies, DC motors, AC motors and adjustable speed drives. (Typically Offered: Spring)

EE 4550: Introduction to Energy Distribution Systems
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3030 *and Credit or concurrent enrollment in EE 3240*
Overhead and underground distribution system descriptions and characteristics, load descriptions and characteristics, overhead line and underground cable models, distribution transformers, power flow and fault analysis, overcurrent protection, power factor correction, system planning and automation, and economics in a deregulated environment. (Typically Offered: Fall)

EE 4560: Power System Analysis I
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3030 *and Credit or concurrent enrollment in EE 3240*
Power transmission lines and transformers, synchronous machine modeling, network analysis, power system representation, load flow. (Typically Offered: Fall)

EE 4570: Power System Analysis II
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3030 *and Credit or concurrent enrollment in EE 3240*
Power system protection, symmetrical components, faults, stability. Power system operations including the new utility environment. (Typically Offered: Spring)

EE 4580: Economic Systems for Electric Power Planning
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 3030 *or* ECON 3010
Evolution of electric power industry. Power system operation and planning and related information systems. Linear and integer optimization methods. Short-term electricity markets and locational marginal prices. Risk management and financial derivatives. Basics of public good economics. Cost recovery models including tax treatment for transmission investments.

EE 4590: Electromechanical Wind Energy Conversion and Grid Integration
(Dual-listed with EE 5590).
Credits: 3. Contact Hours: Lecture 3.
Prereq: Credit or enrollment in EE 4520 and EE 4560
Summary of industry status and expected growth; power extraction from the air stream; operation and modeling of electric machines, and power electronics topologies for wind energy conversion; analysis of machine-grid power electronic circuits, controller interface, and collector (distribution) networks; treatment of harmonics, flicker, over/under-voltages, filters, low-voltage ride-through, and reactive compensation; relaying; effects on transmission expansion, planning and grid operation and coordination including variability, frequency control, reserves, and electricity markets; overview of storage technologies and hybrid configurations.

EE 4650: Digital VLSI Design
(Cross-listed with CPRE 4650).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Prereq: EE 3300
Digital design of integrated circuits employing very large scale integration (VLSI) methodologies. Technology considerations in design. High level hardware design languages, CMOS logic design styles, area-energy-delay design space characterization, datapath blocks: arithmetic and memory, architectures and systems on a chip (SOC) considerations. VLSI chip hardware design project. (Typically Offered: Fall)

EE 4750: Automatic Control Systems
Credits: 3. Contact Hours: Lecture 3.
Stability and performance analysis of automatic control systems. The state space, root locus, and frequency response methods for control systems design. PID control and lead-lag compensation. Computer tools for control system analysis and design. (Typically Offered: Fall)

EE 4760: Control System Simulation
Credits: 3. Contact Hours: Lecture 2, Laboratory 3.
Prereq: EE 4750
Theory and practice of linear, nonlinear, and logic control systems, with hands-on labs on Modeling and Control of: Motor (model identification and validation, speed and position control using PID), Double-hinged inverted pendulum (model identification and validation, balance control using linearization and state-feedback, and swing-up control using sliding-mode), Quadcopter (model identification and validation, navigation and obstacle avoidance control using PID), PLC Assembly-line (ladder logic control for start/stop, sorting, assembly, and discharge using constructs of XIC/XIO/Timer/Counter/OSF/FIFO). (Typically Offered: Spring)

EE 4880: Eddy Current Nondestructive Evaluation
(Dual-listed with EE 5880/ MSE 5880). (Cross-listed with MATE 4880).
Credits: 3. Contact Hours: Lecture 3.
Prereq: MATH 2650 *and (*MATE 2160 *or* MATE 2730 *or* MATE 3920 *or EE 3110 or* PHYS 3640*)*
Electromagnetic fields of various eddy current probes. Probe field interaction with conductors, crack and other material defects. Ferromagnetic materials. Layered conductors. Elementary inversion of probe signals to characterize defects. Special techniques including remote-field, transient, potential drop nondestructive evaluation and the use of Hall sensors. Practical assignments using a 'virtual' eddy current instrument will demonstrate key concepts. Offered odd-numbered years. (Typically Offered: Fall)

EE 4890: Survey of Remote Sensing Technologies
(Dual-listed with MTEOR 5890/ EE 5890/ ENSCI 5890/ GEOL 5890/ NREM 5890). (Cross-listed with MTEOR 4890/ ENSCI 4890/ GEOL 4890/ NREM 4890).
Credits: 3. Contact Hours: Lecture 3.
Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S. (Typically Offered: Fall)

EE 4890L: Satellite Remote Sensing Laboratory
(Dual-listed with MTEOR 5890L/ EE 5890L/ GEOL 5890L/ NREM 5890L). (Cross-listed with MTEOR 4890L/ GEOL 4890L/ NREM 4890L).
Credits: 1. Contact Hours: Laboratory 3.
*Prereq: Completion or concurrent enrollment in MTEOR/GEOL/ NREM/*EE 4890*/5890*
Processing and analysis of satellite sensor data (optical and radar). Provides practical applications in an environmental context. (Typically Offered: Fall)

EE 4900: Independent Study
Credits: 1-30. Repeatable.
Prereq: Senior classification in Electrical Engineering; Permission of Department
Investigation of an approved topic commensurate with the student's prerequisites.

EE 4900H: Independent Study: Honors
Credits: 1-30. Repeatable.
Prereq: Senior classification in Electrical Engineering; Permission of Department
Investigation of an approved topic commensurate with the student's prerequisites.

EE 4910: Senior Design Project I and Professionalism
(Cross-listed with CPRE 4910/ SE 4910).
Credits: 3. Contact Hours: Lecture 2, Laboratory 3.
Prereq: CPRE or CYBE or EE major: Credit or enrollment in CPRE 3080 *or EE 3220,* ENGL 3140 *or* ENGL 3140H *or* ENGL 3090*, (*CPRE 3940 *or EE 3940) or* CPRE 2320 *or (*CPRE 2340 *or* CYBE 2340*). SE major:* SE 3170 *and* SE 3390*,* ENGL 3140 *or* ENGL 3140H *or* ENGL 3090*. Co-req:* CPRE 3080 *or* COMS 3520
Preparing for entry to the workplace. Selected professional topics. Use of technical writing skills in developing project plan and design report; design review presentation. First of two-semester team-oriented, project design and implementation experience. (Typically Offered: Fall, Spring)

EE 4920: Senior Design Project II
(Cross-listed with CPRE 4920/ SE 4920).
Credits: 2. Contact Hours: Lecture 1, Laboratory 3.
Prereq: CPRE 4910 *or EE 4910*
Second semester of a team design project experience. Emphasis on the successful implementation and demonstration of the design completed in EE 4910, CPRE 4910, or SE 4910 and the evaluation of project results. Technical writing of fil project report; oral presentation of project achievements; project poster. (Typically Offered: Fall, Spring)

EE 4940: Portfolio Assessment
(Cross-listed with CPRE 4940).
Credits: Required. Contact Hours: Lecture 1.
Prereq: CPRE 2320 *or EE 2320 or* CYBE 2340*; credit or concurrent enrollment in* CPRE 4910 *or EE 4910*
Portfolio update and evaluation. Portfolios as a tool to enhance career opportunities. Offered on a satisfactory-fail basis only.

EE 4960: Modern Optics
(Cross-listed with PHYS 4960).
Credits: 3. Contact Hours: Lecture 3.
Prereq: Credit or enrollment in PHYS 3220*,* PHYS 3650*, and* PHYS 4800
Review of wave and electromagnetic theory; topics selected from: reflection/refraction, interference, geometrical optics, Fourier analysis, dispersion, coherence, Fraunhofer and Fresnel diffraction, holography, quantum optics, nonlinear optics. (Typically Offered: Fall)

Courses primarily for graduate students, open to qualified undergraduates:

EE 5010: Analog and Mixed-Signal VLSI Circuit Design Techniques
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Design techniques for analog and mixed-signal VLSI circuits. Amplifiers; operational amplifiers, transconductance amplifiers, finite gain amplifiers and current amplifiers. Linear building blocks; differential amplifiers, current mirrors, references, cascading and buffering. Performance characterization of linear integrated circuits; offset, noise, sensitivity and stability. Layout considerations, simulation, yield and modeling for high-performance linear integrated circuits. (Typically Offered: Fall)

EE 5030: Power Management Integrated Circuits
Credits: 3. Contact Hours: Lecture 3.
*Prereq: (*EE 4350 *or credit or concurrent enrollment in EE 5010) or Graduate Classification*
Introducing in-depth chip-level power management integrated circuit (PMIC) designs, including switching power converters, linear regulators, charge pumps and other types of PMICs. Steady-state and dynamic response analysis and optimization of linear regulators and switching power converters with different control methodologies, such as voltage-/current-/band-band control. Chip-level circuit design considerations, optimizations and cadence simulations for PMICs, including system and block-level circuits, such as voltage reference, current source and current mirror, current sensor, ramp generator, non-overlapping power stage, and other circuits. Offered even-numbered years. (Typically Offered: Fall)

EE 5050: CMOS and BiCMOS Data Conversion Circuits
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Theory, design and applications of data conversion circuits (A/D and D/A converters) including: architectures, characterization, quantization effects, conversion algorithms, spectral performance, element matching, design for yield, and practical comparators, implementation issues. Offered even-numbered years. (Typically Offered: Spring)

EE 5060: Design of CMOS Phase-Locked Loops
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Analysis and design of phase-locked loops implemented in modern CMOS processes including: architectures, performance metrics, and characterization; noise and stability analysis; and design issues of phase-frequency detectors, charge pumps, loop filters (passive and active), voltage controlled oscillators, and frequency dividers.

EE 5070: VLSI Communication Circuits
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Phase-locked loops, frequency synthesizers, clock and data recovery circuits, theory and implementation of adaptive filters, low-noise amplifiers, mixers, power amplifiers, transmitter and receiver architectures. Offered odd-numbered years. (Typically Offered: Spring)

EE 5080: Filter Design and Applications
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Filter design concepts. Approximation and synthesis. Transformations. Continuous-time and discrete time filters. Discrete, active and integrated synthesis techniques.

EE 5090: Mixed-Signal IC Testing and Built In Self Test
Credits: 3. Contact Hours: Lecture 3.
Introduction to mixed-signal IC testing; measurement uncertainty and test validity; IEEE standard test algorithms; high performance test and built-in self test challenges; new mixed-signal test algorithms and techniques to reduce data acquisition to relax instrumentation requirements, to simplify test setup, to improve test validity, and/or to enable co-testing of heterogeneous functions. (Typically Offered: Fall, Spring, Summer)

EE 5100: Topics in Electromagnetics
Credits: 1-3. Contact Hours: Lecture 3.
Repeatable.

EE 5120: Advanced Electromagnetic Field Theory I
Credits: 3. Contact Hours: Lecture 3.
Review of static electric and magnetic fields. Maxwell's equations. Circuit concepts and impedance elements. Propagation and reflection of plane waves in isotropic media. Guided electromagnetic wave. Characteristics of common waveguides and transmission lines. Propagation in anisotropic media. Special theorems and concepts. Radiation and scattering. (Typically Offered: Fall)

EE 5130: Advanced Electromagnetic Field Theory II
Credits: 3. Contact Hours: Lecture 3.
Green's functions, perturbational and variational techniques. Analysis of microstrip lines and interconnects. Spectral domain approach, waves in layered media. Integral equations and method of moments. Inverse scattering. Electromagnetic applications. (Typically Offered: Spring)

EE 5140: Microwave Engineering
(Dual-listed with EE 4140).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Principles, analyses, and instrumentation used in the microwave portion of the electromagnetic spectrum. Wave theory in relation to circuit parameters. S parameters, couplers, discontinuities, and microwave device equivalent circuits. RF amplifier design, microwave sources, optimum noise figure and maximum power designs. Microwave filters and oscillators. (Typically Offered: Fall)

EE 5160: Computational Methods in Electromagnetics
Credits: 3. Contact Hours: Lecture 3.
Maxwell's equations. Differential equation based methods. Finite difference and finite difference time domain methods, boundary conditions. Finite element method and applications to the analysis of practical devices. Integral equation based methods. Electric and magnetic field integral equations. Matrix solvers. Fast solution methods. (Typically Offered: Spring)

EE 5170: Electromagnetic Radiation, Antennas, and Propagation
(Dual-listed with EE 4170).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Fundamental antenna concepts. Radiation from wire-and aperture-type sources. Radio transmission formulas. Wave and antenna polarization. Antenna arrays. Modern antenna topics. Practical antenna design. Antenna noise. Radiowave propagation in the presence of the earth and its atmosphere. Antenna measurements and computer aided analysis. (Typically Offered: Spring)

EE 5180: Microwave Remote Sensing
(Cross-listed with AGRON 5180/ MTEOR 5180).
Credits: 3. Contact Hours: Lecture 3.
Microwave remote sensing of Earth's surface and atmosphere using satellite-based or ground-based instruments. Specific examples include remote sensing of atmospheric temperature and water vapor, precipitation, ocean salinity, and soil moisture. Offered even-numbered years. (Typically Offered: Spring)

EE 5190: Magnetism and Magnetic Materials
(Dual-listed with EE 4190/ MATE 4190). (Cross-listed with MSE 5190).
Credits: 3. Contact Hours: Lecture 3.
Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenome. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, magnetic measurements of properties for materials evaluation. Offered odd-numbered years. (Typically Offered: Fall)

EE 5210: Advanced Communications
Credits: 3. Contact Hours: Lecture 3.
Digital communication systems overview. Characterization of communication channels. Digital modulation and demodulation design and performance analysis. Channel capacity and error-control coding concepts. Waveform design for band-limited channels. Equalization. Wireless fading channels and performance. (Typically Offered: Fall)

EE 5220: Cognitive Radio Networks
(Cross-listed with CPRE 5220).
Credits: 3. Contact Hours: Lecture 3.
Topics on cognitive radio networks: Cognitive Radio Networks Architecture; Software Defined Radio Architecture; Spectrum Sensing; Spectrum management; Spectrum Sharing; Spectrum Mobility; Applications of Cognitive Radio Networks. Offered irregularly. (Typically Offered: Fall)

EE 5230: Random Processes for Communications and Signal Processing
Credits: 3. Contact Hours: Lecture 3.
Axioms of probability; Repeated trials; Functions of a random variable and multiple random variables: covariance matrix, conditional distribution, joint distribution, moments, and joint moment generating function; Mean square estimation; stochastic convergence; Some important stochastic processes: Random walk, Poisson, Wiener, and shot noise; Markov chaines; Power spectral analysis; Selected applications.

EE 5240: Digital Signal Processing
Credits: 3. Contact Hours: Lecture 3.
Review: sampling and reconstruction of signals; discrete-time signals, systems, and transforms. Multi-rate digital signal processing and introduction to filter banks. Optimal linear filtering and prediction. Introductions to adaptive filtering and spectral estimation. Applications. (Typically Offered: Fall)

EE 5260: Deep Learning: Theory and Practice
Credits: 3. Contact Hours: Lecture 3.
Review of basic theoretic tools such as linear algebra and probability. Machine learning basics will then be introduced to motivate deep learning networks. Different deep learning network architectures will be studied in detail, including their training and implementations. Applications and research problems will also be surveyed at the end of the class.

EE 5270: Detection and Estimation Theory
Credits: 3. Contact Hours: Lecture 3.
Statistical estimation theory and performance measures: maximum likelihood estimation, Cramer-Rao bound, Bayesian estimation, optimal demodulation, signal design. Introduction to graphical models. Hidden Markov models and Kalman filter. Classical statistical decision theory, decision criteria, binary and composite hypothesis tests. Error probability and Chernoff bound. Applications. (Typically Offered: Spring)

EE 5290: Data Analytics in Electrical and Computer Engineering
(Cross-listed with CPRE 5290).
Credits: 3. Contact Hours: Lecture 3.
Introduces a variety of data analytics techniques - particularly those relevant for electrical and computer engineers - from a foundational perspective. Topics to be covered include techniques for classification, visualization, and parameter estimation, with applications to signals, images, matrices, and graphs. Emphasis will be placed on rigorous analysis as well as principled design of such techniques. (Typically Offered: Spring)

EE 5310: Micro and Nano Systems and Devices
Credits: 3. Contact Hours: Lecture 3.
Fundamentals of modeling and design of micro-nanosystems and devices based on various operational mechanisms. Significant hands-on experience using commercial software COMSOL to design and model micro-nanosystems and devices for biomedical and biomedicine applications among others. Experimental hands-on experience to operate the fabricated micro-nanosystems and devices in the instructor's research lab.

EE 5320: Microelectronics Fabrication Techniques
(Dual-listed with EE 4320/ MATE 4320). (Cross-listed with MSE 5320).
Credits: 4. Contact Hours: Lecture 2, Laboratory 4.
Techniques used in modern integrated circuit fabrication, including diffusion, oxidation, ion implantation, lithography, evaporation, sputtering, chemical-vapor deposition, and etching. Process integration. Process evaluation and final device testing. Extensive laboratory exercises utilizing fabrication methods to build electronic devices. Use of computer simulation tools for predicting processing outcomes. Recent advances in processing CMOS ICs and micro-electro-mechanical systems (MEMS).

EE 5350: Physics of Semiconductors
(Cross-listed with PHYS 5350).
Credits: 4. Contact Hours: Lecture 3, Laboratory 3.
Basic elements of quantum theory, Fermi statistics, motion of electrons in periodic structures, crystal structure, energy bands, equilibrium carrier concentration and doping, excess carriers and recombination, carrier transport at low and high fields, space charge limited current, photo-conductivity in solids, phonons, optical properties, amorphous semiconductors, heterostructures, and surface effects. Laboratory experiments on optical properties, carrier lifetimes, mobility, defect density, doping density, photo-conductivity, diffusion length of carriers.

EE 5360: Physics of Semiconductor Devices
(Cross-listed with PHYS 5360).
Credits: 3. Contact Hours: Lecture 3.
Prereq: EE 5350
P-n junctions, band-bending theory, tunneling phenomena, Schottky barriers, heterojunctions, bipolar transistors, field-effect transistors, negative-resistance devices and optoelectronic devices.

EE 5370: Electronic Properties of Materials
(Dual-listed with EE 4370/ MATE 4370). (Cross-listed with MSE 5370).
Credits: 3. Contact Hours: Lecture 3.
Magnetic fields, flux density and magnetization. Magnetic materials, magnetic measurements. Magnetic properties of materials. Domains, domain walls, domain processes, magnetization curves and hysteresis. Types of magnetic order, magnetic phases and critical phenomena. Magnetic moments of electrons, theory of electron magnetism. Technological application, soft magnetic materials for electromagnets, hard magnetic materials, permanent magnets, magnetic recording technology, biomedical applications of magnetism, magnetic evaluation of materials. (Typically Offered: Spring)

EE 5380: Optoelectronic Devices and Applications
(Dual-listed with EE 4380).
Credits: 3. Contact Hours: Lecture 3.
Transmission and reflection of electromagnetic plane waves. Propagation in dielectric and fiber optic waveguides. LED and laser operating principles and applications. Photodetectors and solar cells. Optical modulation and switching.

EE 5520: Energy System Planning
Credits: 3. Contact Hours: Lecture 3.
Characteristics of bulk energy conversion, storage, and transport technologies. Environmental legislation. Modeling of electricity markets. Evaluation of sustainability and resiliency. Types of planning analyses: economic, multi-sector, long-term, national. Planning tools and associated optimization methods.

EE 5530: Steady State Analysis
Credits: 3. Contact Hours: Lecture 3.
Power flow, economic dispatch, unit commitment, electricity markets, automatic generation control, sparse matrix techniques, interconnected operation, voltage control. (Typically Offered: Fall)

EE 5540: Power System Dynamics
Credits: 3. Contact Hours: Lecture 3.
Dynamic performance of power systems with emphasis on stability. Modeling of system components and control equipment. Analysis of the dynamic behavior of the system in response to small and large disturbances. (Typically Offered: Spring)

EE 5550: Advanced Energy Distribution Systems
Credits: 3. Contact Hours: Lecture 3.
Transient models of distribution components, automated system planning and distribution automation, surge protection, reliability, power quality, power electronics and intelligent systems applications.

EE 5560: Power Electronic Systems
Credits: 3. Contact Hours: Lecture 3.
Converter topologies, AC/DC, DC/DC, DC/AC, AC/AC. Converter applications to do motor drives, power supplies, AC motor drives, power system utility applications (var compensators) and power quality.

EE 5590: Electromechanical Wind Energy Conversion and Grid Integration
(Dual-listed with EE 4590).
Credits: 3. Contact Hours: Lecture 3.
Summary of industry status and expected growth; power extraction from the air stream; operation and modeling of electric machines, and power electronics topologies for wind energy conversion; analysis of machine-grid power electronic circuits, controller interface, and collector (distribution) networks; treatment of harmonics, flicker, over/under-voltages, filters, low-voltage ride-through, and reactive compensation; relaying; effects on transmission expansion, planning and grid operation and coordination including variability, frequency control, reserves, and electricity markets; overview of storage technologies and hybrid configurations.

EE 5650: Systems Engineering and Analysis
(Cross-listed with AERE 5650/ IE 5650).
Credits: 3. Contact Hours: Lecture 3.
Introduction to organized multidisciplinary approach to designing and developing systems. Concepts, principles, and practice of systems engineering as applied to large integrated systems. Life cycle costing, scheduling, risk management, functional analysis, conceptual and detail design, test and evaluation, and systems engineering planning and organization. Graduation Restrictions: Not available for degrees in industrial engineering.

EE 5660: Avionics Systems Engineering
(Cross-listed with AERE 5660).
Credits: 3. Contact Hours: Lecture 3.
Avionics functions. Applications of systems engineering principles to avionics. Top down design of avionics systems. Automated design tools. (Typically Offered: Spring)

EE 5700: Systems Engineering Analysis and Design
Credits: 3. Contact Hours: Lecture 3.
Selected topics in abstract algebra, linear algebra, real analysis, functional analysis, and optimization methods in electrical engineering.

EE 5710: Introduction to Convex Optimization
Credits: 3. Contact Hours: Lecture 3.
Introduction to convex optimization problems emerging in electrical engineering. Efficiently solving convex optimization problems with the use of interior point algorithms software. Review of linear algebra, convex functions, convex sets, convex optimization problems, duality, disciplined convex programming, applications to optimal filtering, estimation, control and resources allocations, sensor network, distributed systems.

EE 5730: Random Signal Analysis and Kalman Filtering
(Cross-listed with AERE 5730/ ME 5730).
Credits: 3. Contact Hours: Lecture 3.
Elementary notions of probability. Random processes. Autocorrelation and spectral functions. Estimation of spectrum from finite data. Response of linear systems to random inputs. Discrete and continuous Kalman filter theory and applications. Smoothing and prediction. Linearization of nonlinear dynamics. (Typically Offered: Fall)

EE 5740: Optimal Control
(Cross-listed with AERE 5740/ ME 5740).
Credits: 3. Contact Hours: Lecture 3.
The optimal control problem. Variational approach. Pontryagin's principle, Hamilton-Jacobi equation. Dynamic programming. Time-optimal, minimum fuel, minimum energy control systems. The regulator problem. Structures and properties of optimal controls. (Typically Offered: Spring)

EE 5750: Introduction to Robust Control
(Cross-listed with AERE 5750/ ME 5750).
Credits: 3. Contact Hours: Lecture 3.
Introduction to modern robust control. Model and signal uncertainty in control systems. Uncertainty description. Stability and performance robustness to uncertainty. Solutions to the H2, Hoo, and I1 control problems. Tools for robustness analysis and synthesis.

EE 5760: Digital Feedback Control Systems
(Cross-listed with AERE 5760/ ME 5760).
Credits: 3. Contact Hours: Lecture 3.
Sampled data, discrete data, and the z-transform. Design of digital control systems using transform methods: root locus, frequency response and direct design methods. Design using state-space methods. Controllability, observability, pole placement, state estimators. Digital filters in control systems. Microcomputer implementation of digital filters. Finite wordlength effects. Linear quadratic optimal control in digital control systems. Simulation of digital control systems. (Typically Offered: Fall)

EE 5770: Linear Systems
(Cross-listed with AERE 5770/ ME 5770/ MATH 5770).
Credits: 3. Contact Hours: Lecture 3.
Linear algebra review. Least square method and singular value decomposition. State space modeling of linear continuous-time systems. Solution of linear systems. Controllability and observability. Canonical description of linear equations. Stability of linear systems. State feedback and pole placements. Observer design for linear systems. (Typically Offered: Fall)

EE 5780: Nonlinear Systems
(Cross-listed with AERE 5780/ ME 5780/ MATH 5780).
Credits: 3. Contact Hours: Lecture 3.
Linear vs nonlinear systems. Phase plane analysis. Bifurcation and center manifold theory. Lyapunov stability. Absolute stability of feedback systems. Input-output stability. Passivity theory and feedback linearization. Nonlinear control design techniques. (Typically Offered: Spring)

EE 5810X: Quantum Information Theory
Credits: 3. Contact Hours: Lecture 3.
Repeatable.
Prereq: MATH 2070 *or* MATH 3170
Overview of quantum information theory. Introduction to the basic principles of quantum mechanics; formulation of quantum channels; trace and fidelity distance measures; quantum entropy and its relation to classical entropy; information measures for quantum channels; quantum communication and quantum entanglement assisted classical communication. (Typically Offered: Fall)

EE 5880: Eddy Current Nondestructive Evaluation
(Dual-listed with EE 4880/ MATE 4880). (Cross-listed with MSE 5880).
Credits: 3. Contact Hours: Lecture 3.
Electromagnetic fields of various eddy current probes. Probe field interaction with conductors, crack and other material defects. Ferromagnetic materials. Layered conductors. Elementary inversion of probe signals to characterize defects. Special techniques including remote-field, transient, potential drop nondestructive evaluation and the use of Hall sensors. Practical assignments using a 'virtual' eddy current instrument will demonstrate key concepts. Offered odd-numbered years. (Typically Offered: Fall)

EE 5890: Survey of Remote Sensing Technologies
(Dual-listed with MTEOR 4890/ EE 4890/ ENSCI 4890/ GEOL 4890/ NREM 4890). (Cross-listed with MTEOR 5890/ ENSCI 5890/ GEOL 5890/ NREM 5890).
Credits: 3. Contact Hours: Lecture 3.
Electromagnetic-radiation principles, active and passive sensors, multispectral and hyperspectral sensors, imaging radar, SAR, thermal imaging, lidar. Examples of applications. Also offered online S. (Typically Offered: Fall)

EE 5890L: Satellite Remote Sensing Laboratory
(Dual-listed with MTEOR 4890L/ EE 4890L/ GEOL 4890L/ NREM 4890L). (Cross-listed with MTEOR 5890L/ GEOL 5890L/ NREM 5890L).
Credits: Required. Contact Hours: Laboratory 3.
Processing and analysis of satellite sensor data (optical and radar). Provides practical applications in an environmental context. (Typically Offered: Fall)

EE 5900A: Special Topics: Electromagnetic Theory
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900B: Special Topics: Control Systems
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900E: Special Topics: Computer Engineering
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900F: Special Topics: Electric Power
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900G: Special Topics: Electrical Materials
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900H: Special Topics: Electronic Devices and Circuits
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5900I: Special Topics: Signal Processing
Credits: 1-6. Repeatable.
Prereq: Instructor Permission for Course
Formulation and solution of theoretical or practical problems in electrical engineering.

EE 5920: Seminar in Electrical Engineering
Credits: 1-4. Contact Hours: Lecture 4.
Repeatable, maximum of 8 times.
Prereq: Instructor Permission for Course
Technical seminar presentations on topics in various areas in electrical engineering. It will have the following sections, corresponding to graduate study areas in the department: Bioengineering; Communications, signal processing, and machine learning; Electric power and energy systems; Electromagnetic, microwave, and nondestructive evaluation; Microelectronics and photonics; Systems and controls; and VLSI. Offered on a satisfactory-fail basis only. (Typically Offered: Fall, Spring)

EE 5950: Independent Study
Credits: 1-3. Repeatable, maximum of 6 credits.
Prereq: Instructor Permission for Course
Investigation of an approved topic commensurate with the student's prerequisites. (Typically Offered: Fall, Spring, Summer)

EE 5980: Electrical and Computer Engineering Learning Community Seminar
(Cross-listed with CPRE 5980).
Credits: Required. Contact Hours: Lecture 1.
Introduction to graduate study in Electrical and Computer Engineering at Iowa State University. Building networks, introduction to core requirements, and tools and techniques for success. Graduation Restriction: ECpE. Offered on a satisfactory-fail basis only.

EE 5990: Creative Component
Credits: 1-30. Repeatable.
Prereq: Instructor Permission for Course

Courses for graduate students:

EE 6170: Advanced Topics in Antenna Analysis and Design
Credits: 3. Contact Hours: Lecture 3.
Introduction to several advanced topics related to antenna design, analysis, and fabrication; beyond what is covered in EE 4170 or EE 5170 which primarily addresses fundamental foundations of antenna theory, analysis, and design. Topics include: Radiation integrals and methods; Polarization, in a comprehensive manner; antenna synthesis and continuous sources; Integral equations, self and mutual impedances, and vector effective length; Aperture antennas and field calculation fundamentals; Near-field to far-field transformation; Microstrip antennas; and Reconfigurable antenna fundamentals. Assignments will involve the use of numerical electromagnetic solvers such as HFSS and CST Microwave Studio. Expands skill sets in the area of numerical EM analysis, which is a critical issue for practical and advanced antenna design problems. (Typically Offered: Fall)

EE 6210: Coding Theory
Credits: 3. Contact Hours: Lecture 3.
Fundamentals of error-control coding techniques: coding gain, linear block codes. Galois fields. Cyclic codes: BCH, Reed-Solomon. Convolutional codes and the Viterbi algorithm. Trellis-coded modulation. Iterative decoding. Recent developments in coding theory.

EE 6220: Information Theory
Credits: 3. Contact Hours: Lecture 3.
Information system overview. Entropy and mutual information. Data Compression and source encoding. Discrete memoryless channel capacity. Noisy channel coding theorem. Rate distortion theory. Waveform channels. Advanced topics in information theory.

EE 6230X: High-Dimensional Probability and Linear Algebra for Machine Learning
(Cross-listed with MATH 6230X).
Credits: 3. Contact Hours: Lecture 3.
Repeatable.
Key topics from non-asymptotic random matrix theory: Bounds on minimum and maximum singular values of many classes of high-dimensional random matrices, and on sums of a large number of random matrices. Chaining. Other linear algebra and probability concepts commonly used in Theoretical Machine Learning research. Discussion of recent papers in this area.

EE 6530: Advanced Topics in Electric Power System Engineering
Credits: 3. Contact Hours: Lecture 3.
Repeatable.
Advanced topics of current interest in electric power system engineering.

EE 6740: Advanced Topics in Systems Engineering
Credits: 3. Contact Hours: Lecture 3.
Repeatable.
Advanced topics of current interest in the areas of control theory, stochastic processes, digital signal processing, and image processing.

EE 6930: Entrepreneurship for Graduate Students in Science and Engineering
(Cross-listed with AGRON 6930/ BCB 6930/ ENGR 6930/ GENET 6930/ ME 6930).
Credits: 1. Contact Hours: Lecture 3.
Repeatable, maximum of 2 credits.
Understanding key topics of starting a technology based company, from development of technology-led idea to early-stage entrepreneurial business. Concepts discussed include: entrepreneurship basics, starting a business, funding your business, protecting your technology/ business IP. Subject matter experts and successful, technology-based entrepreneurs will provide real world examples from their experience with entrepreneurship. Learn about the world class entrepreneurship ecosystem at ISU and Central Iowa. Offered on a satisfactory-fail basis only. (Typically Offered: Fall, Spring)

EE 6970: Engineering Internship
(Cross-listed with CPRE 6970).
Credits: Required. Repeatable.
One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

EE 6990: Research
Credits: 1-30. Repeatable.
Prereq: Instructor Permission for Course