

ELECTRICAL AND COMPUTER ENGINEERING

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Chair

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Faculty with Research Interests

For more information regarding faculty visit the Department of Electrical and Computer Engineering website.

The Department of Electrical and Computer Engineering offers academic programs in advanced study to graduates with technical backgrounds in preparation for careers in industry and in academic research. In addition to the doctoral and master's degrees, which are granted in recognition of research contribution and coursework, the department offers a number of professional master's degrees and certificate programs to enable practicing engineers to pursue continuing education in their areas of interest.

Faculty members are engaged in research in the forefront of their fields, with funding derived from industrial and government research grants and contracts, which provide support to graduate students in the form of research assistantships, in addition to the development and the maintenance of the research facilities. The department also offers a number of fellowships and teaching assistantships on a competitive basis.

Admission to graduate study in one of the programs requires the completion of an undergraduate degree or its equivalent in electrical engineering, computer engineering, or other engineering disciplines from an accredited university. Individuals with backgrounds in other fields of engineering are required to complete courses in the core undergraduate curriculum before commencing graduate work.

For many years, the graduate programs offered by the department have facilitated professionals in industry to advance their knowledge through the pursuit of graduate degrees. The Office of Digital Learning, the interactive distance learning facility of Illinois Institute of Technology, provides support to continuing education by making numerous courses accessible via the Internet and a regional multi-channel television network serving almost 20 industrial organizations in the metropolitan Chicago area.

Research Centers and Facilities

The department operates research laboratories for work in CAD (Computer-Aided Design), for VLSI (Very- Large-Scale Integration), and SoC (System-on-Chip) circuit design, communications, computer networking, wireless networks, network security, cloud computing, cyber physical systems, embedded computing, image processing, medical imaging, data mining, microwave electronics, power systems, smart grids, signal processing, and ultrasonic imaging. The Electric Power and Power Electronics Center supports research initiatives with support from industry and government in the areas of power systems, power electronics, electric machines, motor drives, and vehicular power systems. The Medical Imaging Research Center conducts research in numerous forms for imaging and data analysis, and includes the Advance X-ray Imaging Laboratory (AXIL), which is developing new types of x-ray devices. The department also collaborates with and utilizes the research resources of the Pritzker Institute of Biomedical Science and Engineering and nearby national laboratories.

The department has state-of-the-art computer systems to enhance and extend the generally available system in the university. A primary resource is a network of more than 100 high-performance workstations, file servers, and computer servers, computer clusters for both CPU and GPU (Graphics Processing Unit) based computing, running the Windows/Unix/Linux/OS X operating system. With mass storage, CD-ROM drives, tape drives, and accelerated graphics, these systems provide students and researchers with an array of software tools including: programming languages (C, C++, Java, FORTRAN, Python, Perl, CUDA, Open CL, etc.), software development tools, software and hardware simulators, and electronic computer-aided design packages from companies such as Cadence, Synopsys, Avanti, Synplicity, Xilinx, Altera, Mentor Graphics, EPRI, and ESCA.

In addition to the workstations, the department maintains a collection of PCs for ECE students, including a set of machines that can be dedicated to hardware/software projects. The computers are connected via high-speed Ethernet, (wired and wireless), which in turn is connected to the university's backbone and the Internet.

Research Areas

Active research programs are conducted in the general areas of communications systems, wireless networks, computer systems, computer networks, wireless security, cloud computing and micro-electronics, electromagnetics and electronics, power and control systems, and signal and image processing.

Energy/Environment/Economics (E3)

The Energy/Environment/Economics (E3) program was developed to respond to the rapidly changing needs of the energy industry by providing the interdisciplinary research and training required to produce a new breed of engineer—one who specializes in energy technologies and who understands the associated environmental and sustainability issues and economic forces that drive technology choice.

The E3 specialization requires an interdisciplinary thesis in an E3 area of research for M.S. and Ph.D. degrees, and an interdisciplinary graduate project or additional energy and sustainability courses for professional master's degrees. Graduate students in E3 should also be enrolled in fundamental courses related to the topics of energy, environment, and economics. E3 is designed primarily for students majoring in engineering who are planning careers in energy-related fields. This interdisciplinary training prepares students to be not only creative and expert in a specialized area of energy extraction, conversion, or utilization, but also to possess a broad knowledge base of different energy sources, of sustainability issues related to energy extraction, conversion, and utilization, and of the impact of sustainability principles on the design and operation of energy systems. Furthermore, students will gain sufficient knowledge of sustainability and regulatory issues to enable them to make more viable technology choices.

Admission Requirements

Minimum Cumulative Undergraduate GPA

3.0/4.0

Minimum GRE Scores

- Master's/Master of Science: 304 (quantitative + verbal), 3.5 (analytical writing)
- Ph.D.: 304 (quantitative + verbal), 3.5 (analytical writing)

Minimum TOEFL Scores

80/550 (internet-based/paper-based test scores)

Meeting the minimum GPA and test score requirements does not guarantee admission. Test scores and GPA are just two of several important factors considered. Professional master's degrees in electrical and computer engineering, network engineering, telecommunication and software engineering, power engineering, biomedical images and signals, VLSI and microelectronics, and electricity markets do not require GRE scores for applicants who hold undergraduate degrees from universities in the United States with a minimum cumulative GPA of 3.0/4.0.

Admission to the master's degree programs normally requires a bachelor's degree from an accredited institution in electrical engineering or computer engineering. Applicants with backgrounds in other fields with proficiency in engineering sciences, physics, mathematics, or computer science, gained through prior coursework or professional experience, are also eligible for admission, but will be required to demonstrate proficiency in the subject matter covered in undergraduate courses that are prerequisites for the chosen graduate program.

Proficiency may be demonstrated by passing a written exam or by taking and passing, with a grade of "B" or better, prerequisite undergraduate courses at the university. Specific course prerequisites for each degree program are listed within the program description.

Admission to the doctoral program requires a master's degree. Each entering degree-seeking graduate student is assigned a temporary academic adviser who will provide initial guidance to the candidate. As their research and other academic interests become defined, students may opt to select a new permanent adviser.

Non-degree graduate students should consult with the department adviser. Students are responsible for following the guidelines of the graduate programs set by the department, in conjunction with the regulations of the Graduate College.

Degrees Offered

- Master of Biomedical Imaging and Signals
- Master of Computational Engineering, Optimization, Machine Vision, and Decision Making Track
- Master of Computer Engineering in Internet of Things
- Master of Cyber Security Engineering
- Master of Electrical and Computer Engineering
- Master of Network Engineering
- Master of Power Engineering
- Master of Telecommunications and Software Engineering
- Master of VLSI and Microelectronics

- Master of Engineering in Advanced Manufacturing, Automation and Control Systems Track
- Master of Engineering in Artificial Intelligence for Computer Vision and Control
- Master of Engineering in Energy Systems, Energy Transmission and Markets Track
- Master of Engineering in Wireless Communications and Computer Networks
- Master of Science in Computer Engineering
- Master of Science in Electrical Engineering
- Doctor of Philosophy in Computer Engineering
- Doctor of Philosophy in Electrical Engineering

Dual Degree Program

- Master of Science in Computer Engineering and Electrical Engineering

Joint Degree Programs

- Master of Electricity Markets (with Finance)

Interdisciplinary Programs

- Master of Electrical and Computer Engineering with Specialization in Energy/Environment/Economics (E3)
- Master of Science in Electrical Engineering with Specialization in Energy/Environment/Economics (E3)
- Doctor of Philosophy in Electrical Engineering with Specialization in Energy/Environment/Economics (E3)

Certificate Programs

Certificate programs provide a student with post-baccalaureate knowledge in an area of specialization within electrical and computer engineering. Students in these programs register as certificate non-degree seeking students. Certificates are granted upon completion of all course requirements in the chosen specialization area, as listed below, with a minimum GPA of 3.0. Certificate programs must be completed within five years.

It is the student's responsibility to meet all course prerequisites. Any student admitted to a master's degree program offered by the department may apply coursework completed in the certificate program toward the master's degree requirements.

- Advanced Electronics
- Applied Electromagnetics
- Communication Systems
- Computer Engineering
- Control Systems
- Electricity Markets
- Power Electronics
- Power Engineering
- Signal Processing
- Wireless Communications Engineering

Course Descriptions

ECE 501

Artificial Intelligence and Edge Computing

This course introduces methods in designing contemporary smart systems utilizing artificial intelligence, machine vision, and their applications. Topics include linear regression, logistic regression, multilayer neural networks, supervised/unsupervised learning, convolutional networks, and recurrent neural networks. This course also covers topics in deep learning algorithms and artificial intelligence structures optimized for low power embedded computing platforms (Edge Artificial Intelligence) with applications in machine vision, robotics, internet of things, smart grids and autonomous systems. In addition, students are required to complete an open-ended design project in one of the advanced topics, for example, numerical in Deep Neural Networks, Convolutional Networks, and Recurrent Neural Networks.

Lecture: 3 Lab: 0 Credits: 3

ECE 502

Basic Network Theory

Steady-state analysis of linear networks. Introduction to topology and the derivation of mesh, nodal & terminal pair relations using topological concepts with applications to computer-aided analysis of networks. Numerical techniques for network analysis and optimization.

Lecture: 3 Lab: 0 Credits: 3

ECE 503

5G Wireless Network: Architecture, New Radio, and Security

The primary distinguishing features of 5th Generation (5G) wireless network are its operations in the mm wave region for effectively handling Machine Type Communication (MTC) for supporting secure and tactile Internet of Things (IoT) and cloud based virtualization and operations. This course covers the details of 5G Cloud based Radio Access Network (C-RAN) and the 5G Core along with how the cloud infrastructure creates a very powerful flexible, secure, and reliable network through virtualization and Network Slicing. Unique features of 5G New Radio (NR) including accessing and duplexing schemes, mm wave operation, and enhanced coverage are discussed. The capabilities of the 5G Core which provides a very flexible usage of network resources are discussed. Projects will entail application to a selected set of use cases in the domains of smart city, smart transportation, and e-Health among others.

Lecture: 3 Lab: 0 Credits: 3

ECE 504

Wireless Communication System Design

Fundamentals of first (1G), second (2G), third (3G), and future generation cellular communication systems. This course covers the transition from 1G to 3G systems. Topics included are speech and channel encoders, interleaving, encryption, equalization, modulation formats, multi-user detection, smart antennas, technologies that are used in these transitions, and future generations of cellular systems. Compatibility aspects of digital cellular systems are discussed along with a review of the standards for the industry. TDMA and CDMA systems are covered in detail.

Lecture: 3 Lab: 0 Credits: 3

ECE 505

Applied Optimization for Engineers

Principles of optimization for practical engineering problems, linear programming, nonlinear unconstrained optimization, nonlinear constrained optimization, dynamic programming.

Lecture: 3 Lab: 0 Credits: 3

ECE 506

Analysis of Nonlinear Systems

Graphical and analytical methods, phase plane and singular points, periodic oscillations and limit cycles, forced nonlinear systems, jumps subharmonics and frequency entrainment; stability analysis using Liapunov, Popov and circle criteria; introduction to describing functions.

Lecture: 3 Lab: 0 Credits: 3

ECE 507

Imaging Theory & Applications

Image formation methods including optical (photography), tomography, image formation with arrays of sensors, interferometry, and surface imaging. Technologies of image acquisition including digital cameras, radar/sonar and medical imaging techniques such as magnetic resonance imaging, computed tomography, positron emission tomography, optical imaging, electroencephalography, and magnetoencephalography. Throughout the semester, the course will also focus on the reconstruction of images based on the raw data obtained from various imaging techniques.

Lecture: 3 Lab: 0 Credits: 3

ECE 508

Video Processing and Communications

This course covers the fundamentals of video coding and communications. The principles of source coding for the efficient storage and transmission of digital video will be covered. State-of-the-art video coding standards and error-resilient video coding techniques will be introduced. Recent technologies for robust transmission of video data over wired/wireless networks will be discussed. A detailed overview of architectural requirements for supporting video communications will be presented. Error control and cross-layer optimization techniques for wireless video communications will be covered.

Lecture: 3 Lab: 0 Credits: 3

ECE 509

Electromagnetic Field Theory

Electric and magnetic fields produced by charge and current distributions. Solution of Laplace's and Poisson's equations, time-varying fields and electromagnetic waves. Applications to waveguides and antennas.

Prerequisite(s): ECE 307 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 510**Internet of Things and Cyber Physical Systems**

To introduce students to the fundamentals of Internet of Things (IoT) and embedded computing. This course covers IoT applications, Wireless protocols, Wearable sensors, Home environment sensors, Behavior detection sensors, Data fusion, processing and analysis, Data communications, Architectural design issues of IoT layers, Security and privacy issues in IoT. Simulation mini-projects and lab experiments are based on the lectures given.

Lecture: 3 Lab: 0 Credits: 3

ECE 511**Analysis of Random Signals**

Probability theory, including discrete and continuous random variables, functions and transformations of random variables. Random processes, including correlation and spectral analysis, the Gaussian process and the response of linear systems to random processes.

Lecture: 3 Lab: 0 Credits: 3

ECE 512**Hybrid Electric Vehicle Drives**

Fundamentals of electric motor drives are studied. Applications of semiconductor switching circuits to adjustable speed drives, robotic, and traction are explored. Selection of motor drives, calculating the ratings, speed control, position control, starting, and braking are also covered. Simulation mini-projects and lab experiments are based on the lectures given.

Lecture: 3 Lab: 0 Credits: 3

ECE 513**Communication Engineering Fundamentals**

Review of probability and random processes. AM with noise, FM with noise. Introduction to digital communication. Source coding, signal space analysis, channel modulations, optimum receiver design, channel encoding.

Lecture: 3 Lab: 0 Credits: 3

ECE 514**Digital Communication Principles**

Information transmission fundamentals, including capacity, entropy, Shannon's theorems and source coding. Introduction to rate distortion theory. Advanced digital modulation and demodulation techniques, performance measures. Channel coding and introduction to trellis coded modulation.

Prerequisite(s): (ECE 511 with min. grade of C and ECE 513 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 515**Modern Digital Communications**

Review of modulation and coding. Trellis coded modulation. Digital signaling over fading multipath channels. Spread spectrum signals for digital communications. Multiple access systems, time-division multiple access, code-division multiple access, and frequency-division multiple access. Advanced communications systems.

Prerequisite(s): (ECE 511 with min. grade of C and ECE 513 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 516**Coding for Distributed Storage Systems**

Distributed storage systems, such as data centers, are becoming a vital infrastructure of today's society by allowing to store reliably large amounts of data and make it accessible anywhere and anytime. The goal of this course is to train students with the different mathematical and engineering tools that are needed when studying and designing codes and algorithms for data reliability and security in these large-scale systems. The course will cover relevant topics in information theory, coding theory, graph theory, and wireless communications in addition to the active on-going research in this area.

Prerequisite(s): ECE 511 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 517**Modern Wireless Network Protocols and Standards**

This course introduces cutting-edge wireless networking technologies with focus on the network protocols and standards of the current and next generation wireless networks including cellular networks, wireless local area networks, and wireless ad hoc networks. Specifically, it will cover topics relevant to wireless communications, radio resource management, mobility management, wireless medium access control, wireless routing protocols, and wireless TCP protocols.

Prerequisite(s): ECE 407 with min. grade of C or ECE 408 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 518**Computer Cyber Security**

This course gives students a clear understanding of computer and cyber security as threats and defense mechanisms backed by mathematical and algorithmic guarantees. Key topics covered include introductory number theory and complexity theory, cryptography and applications, system security, digital forensics, software and hardware security, and side-channel attacks. Course projects will provide hand-on experiences on languages, libraries, and tools supporting state-of-the-art cryptography applications. Students registering for ECE 518 are required to complete additional projects in advanced areas.

Lecture: 3 Lab: 0 Credits: 3

ECE 519**Coding for Reliable Communications**

Encoders and decoders for reliable transmission of digital data over noisy channels. Linear block codes, cyclic codes, BCH codes, convolutional codes. Burst error correcting codes. Maximum likelihood decoding of convolutional codes. Performance of block and convolutional codes in additive white Gaussian channel.

Lecture: 3 Lab: 0 Credits: 3

ECE 520**Information Theory and Applications**

Definition of information; coding of information for transmission over a noisy channel including additive Gaussian noise channels and waveform channels; minimum rates at which sources can be encoded; maximum rates at which information can be transmitted over noisy channels. Information theoretic security. Modern applications of information theory in communications, networking, and other fields.

Prerequisite(s): ECE 511 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 521**Quantum Electronics**

The Schrodinger equation. Matrix formulation. Quantization of lattice vibrations and electromagnetic fields. Optical beams and resonators. The interaction of radiation and atomic systems. Lasers. Optical waveguides and devices. Frequency conversion. Quantum noise. Same as PHYS 521.

Prerequisite(s): ECE 307 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 522**Electromagnetic Compatibility**

Development of design procedures for minimizing interference between electronic circuits and systems. sources of conducted and radiated interference. Interference coupling mechanisms. Shielding theory. Grounding, bonding and filtering methods. special equipment design procedures. Problems associated with digital equipment. Measurement methods.

Prerequisite(s): ECE 307 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 523**Fundamentals of Semiconductor Devices**

The goals of this course are to give students an understanding of the physical and operational principles behind important electronic devices. Semiconductor electron and hole concentrations, carrier transport, and carrier generation and recombination are discussed. P-N junction operation and its application to diodes, solar cells, and LEDs, are developed. The metal-oxide-semiconductor-field-effect transistor (MOSFET) and bipolar junction transistor (BJT) are then discussed. Applications of transistors in analog and digital circuits are introduced. A term project on a particular device topic is required.

Lecture: 3 Lab: 0 Credits: 3

ECE 524**Advanced Electronic Circuit Design**

RF amplifiers and oscillators. Low and high power RF amplifier design techniques. Stability of amplifiers. LC and crystal oscillators. FM demodulators and limiters. Mixer design. Circuit design to minimize intermodulation and other forms of distortion.

Prerequisite(s): (ECE 309 with min. grade of C and ECE 312 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 525**RF Integrated Circuit Design**

Essentials of contemporary RF CMOS integrated circuit analysis and design. Typical RF building blocks in CMOS and BiCMOS technologies, including passive IC components, MOS transistors, RLC tanks, distributed networks, RF amplifiers, voltage reference and biasing circuits, LNA, mixers, power amplifiers, and feedback networks. RF device modeling, Smith chart applications, bandwidth estimation, and stability analysis techniques. RF IC team design projects.

Lecture: 3 Lab: 0 Credits: 3

ECE 526**Active Filter Design**

Analysis and design of linear active filters with emphasis on realizations using operational amplifiers. Sensitivity analysis. Switched capacitor filters.

Prerequisite(s): (ECE 308 with min. grade of C and ECE 312 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 527**Performance Analysis of RF Integrated Circuits**

Essentials of analysis techniques for nonlinear effects and noises in contemporary RF integrated circuit design. Nonlinear and distortion behaviors including inter-modulation, cross-modulation, harmonics, gain compression, desensitization, spurious, etc. Noise effects including thermal, shot, Flicker, burst noises, etc. RF IC devices and circuits including resistors, capacitors, inductors, diodes, BJTs, FETs, low-noise amplifiers, mixers, power amplifiers, etc. Analysis skills for single-stage and multiple-stage networks. RF IC team design projects.

Prerequisite(s): ECE 312 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 528**Application Software Design**

The course provides introduction to languages and environments for application software development utilizing Software as a Service (SaaS) for electrical and computer engineers. Languages addressed include Java, Python, SQL, and JavaScript. Key topics covered include systems development life cycle, client-server architectures, database integration, RESTful service, and data visualization. Programming projects will include the development of a data-rich web application with server back-end that connects mobile devices and Internet of Things using Agile software engineering practices. Differential requirement from ECE 448 is a major final project.

Lecture: 3 Lab: 0 Credits: 3

ECE 529**Advanced VLSI Systems Design**

Advanced design and applications in VLSI systems. The topics of this course include design tools and techniques, clocking issues, complexity management, layout and floor planning, array structures, testing and testability, advanced arithmetic circuitry, transcendental function approximations, architectural issues, signal processing architecture and sub-micron design. Design projects are completed and fabricated by student teams.

Lecture: 3 Lab: 0 Credits: 3

ECE 530**High Performance VLSI IC Systems**

Background and insight into some of the most active performance-related research areas of the field is provided. Issues covered include CMOS delay and modeling, timing and signal delay analysis, low power CMOS design and analysis, optimal transistor sizing and buffer tapering, pipelining and register allocation, synchronization and clock distribution, retiming, interconnect delay, dynamic CMOS design techniques, asynchronous vs. synchronous tradeoffs, BiCMOS, low power design, and CMOS power dissipation. Historical, primary, and recent papers in the field of high-performance VLSI digital and analog design and analysis are reviewed and discussed. Each student is expected to participate in the class discussions and also lead the discussion surveying a particular topic.

Prerequisite(s): ECE 429 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 531**Linear System Theory**

Linear spaces and operators, single and multivariable continuous dynamical systems, controllability and observability. Canonical forms, irreducible realizations. Synthesis of compensators and observers. Composite systems, elements of stability.

Prerequisite(s): ECE 308 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 533**Robust Control**

Uncertain systems; multi-variable control design; linear fractional transformation; uncertainties and small-gain theorem; H-infinity norm; algebraic Riccati equations; H-infinity control; optimality and robustness; design considerations; loop shaping; uncertainty and disturbance estimator; applications and examples.

Prerequisite(s): ECE 438 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 535**Discrete Time Systems**

Discrete systems. Sampling and reconstruction procedures. Transform techniques of analysis and synthesis. State space techniques. Discrete controllability, observability and stability. Compensation and digital controllers.

Prerequisite(s): ECE 438 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 536**Analytical Methods for Power System Economics and Cybersecurity**

Analytical methods for the economic operation of power systems with consideration of transmission losses. Analytical methods for the optimal scheduling of power generation including real power and reactive power. Analytical methods for the estimation of power system state. Analytical methods for the modeling of smart grid cybersecurity. Research project on smart grid cybersecurity.

Prerequisite(s): ECE 319 with min. grade of C or ECE 418 with min. grade of C or ECE 419 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 537**Next Generation Smart Grid**

Paradigm change of power systems; Challenges faced during the paradigm change; Concept of synchronized and democratized (SYNDEM) smart grids; SYNDEM architecture for next-generation smart grids; Technical routes to implement SYNDEM smart grids; Enabling technologies: Three generations of virtual synchronous machines (VSM); Integration of renewables/EV/storage systems through VSM; Integration of flexible loads through VSM; Illinois Tech SYNDEM prototype smart grid.

Lecture: 3 Lab: 0 Credits: 3

ECE 538**Renewable Energies**

Various renewable energy sources such as solar systems, wind powered systems, ocean tides, ocean waves, and ocean thermal are presented. Their operational principles are addressed. Grid connected interfaces for such systems are explained. Research and Simulation mini-projects with emphasis on either machine design, or power electronic circuit analysis, design, and controls, or grid connected renewable systems are assigned to student groups.

Prerequisite(s): ECE 311 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 539**Computer Aided Design of Electric Machines**

Fundamentals of energy conversion will be discussed, which are the foundation of efficient design and operation of motors & generators in modern day automotive, domestic and renewable energy systems. It will further investigate the principles of structural assessment, electromagnetic analysis, dimensional and thermal constraints. Finite Element Analysis (FEA) software-based design projects will be used to model the performance and operation of electric machines.

Lecture: 3 Lab: 0 Credits: 3

ECE 540**Reliability Theory and System Implementation**

Basic probability and modeling techniques on component, subsystem and system levels. MTBF, MTTR and downtime. Hardware, software and cost considerations. Switching systems. Multicomputer and memory configurations.

Lecture: 3 Lab: 0 Credits: 3

ECE 541**Communications Networks Performance Analysis**

This course will cover the probability and queueing theory fundamentals for modern communication networks performance analysis. Applications of the theoretical analysis to modern Internet protocols and machine learning are to be studied. The main topics include: Probability and distributions, random processes, discrete and continuous Markov Chains, queueing systems, probability in machine learning, and applications of theories in modern mobile access control protocols.

Lecture: 3 Lab: 0 Credits: 3

ECE 542**Design and Optimization of Computer Networks**

This course provides comprehensive introduction to network flows with an integrative view of theory, algorithms, and applications. It covers shortest path, maximum flow, and minimum cost flow problems, including a description of new and novel polynomial-time algorithms. It also covers topics from basic network design to protection and restoration design, to multi-layer network design while taking into account routing and flow requirement as applicable in different network architecture, protocol and technologies.

Prerequisite(s): ECE 407 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 543**Computer Network Security**

This course studies computer network security by covering topics such as fundamental cryptographic algorithms; protocol design and analysis for secure communications over Internet; efficient key management infrastructure; strong password protection; attack and security models; practical security protocols in application layer, transport layer, network layer, and link layer. Students registering for ECE 543 are required to complete additional projects in advanced areas.

Prerequisite(s): ECE 407 with min. grade of C or ECE 408 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 544**Wireless and Mobile Networks**

This course provides an overview of different wireless and mobile network standards and systems. The topics covered include cellular networks, satellite networks, wireless local area networks, wireless personal area networks, mobile IP, ad hoc networks, sensor networks, wireless mesh networks and wireless network security.

Lecture: 3 Lab: 0 Credits: 3

ECE 545**Modern Internet Technologies**

This course covers the key technologies that enable the modern Internet with a top-down approach. The main topics include multimedia application and protocols, content distribution networks, edge computing, methodologies for reliable communications, next generation network architecture based on software defined networking, resource virtualization, and key techniques for mobile Internet. This course also deals with the concept of layer based design, strategy for quality of service provisioning, performance analysis based on mathematical modeling, and performance evaluation via practical simulations.

Lecture: 3 Lab: 0 Credits: 3

ECE 546**Wireless Network Security**

This course focuses on selected research topics current interest in wireless network security. This course will cover security and privacy issues in wireless systems, including cellular networks, wireless LAN, mobile ad hoc networks (MANET), wireless mesh networks, sensor networks, vehicular networks, RFID, and ubiquitous computing.

Prerequisite(s): ECE 543 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 548**Energy Harvesting**

Various harvesting techniques such as solar, ocean tides, vibration, linear motion, radio frequency, passive and active human power generation are presented. Their operational principles are addressed. Research and simulations mini-projects with emphasis on power electronic circuit analysis, design, and controls are assigned to student groups.

Prerequisite(s): ECE 311 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 549**Motion Control Systems Dynamics**

Fundamentals and applications of motion control systems, control techniques for high precision motion control, state variable feedback of linear and nonlinear systems, multivariable systems, physical system modeling, graphical analysis, and numerical analysis, and system performance analysis.

Prerequisite(s): ECE 438 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 550**Power Electronic Dynamics and Control**

Modeling and analysis of solid-state switching circuits, parallel module dynamics, multi-converter interactions, resonant converters, feedback control, stability assessment, reduced parts converters, integrated structures, programmable switching regulators, digital switch-mode controllers, and power electronic converter-on-a-chip development.

Prerequisite(s): ECE 411 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 551**Advanced Power Electronics**

Advanced power electronic converters, techniques to model and control switching circuits, resonant converters, Pulse-Width-Modulation (PWM) techniques, soft-switching methods, and low-voltage high-current design issues are studied. Single-phase and multi-phase, controlled and uncontrolled rectifiers and inverters with different operating techniques and their design and control issues are explained.

Prerequisite(s): ECE 411 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 552**Adjustable Speed Drives**

Fundamentals of electric machines, basic principles of variable speed controls, field orientation theory, direct torque control, vector of AC drives, induction machines, switched reluctance and synchronous reluctance motors, permanent magnet brushless DC drives, converter topologies of DC and AC drives, and sensorless operation.

Prerequisite(s): ECE 411 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 553**Power System Planning**

Model development. Interchange capability, interconnections, pooling. Economic generator size and site selection. Concept of reserves, transformers, relays and circuit breakers. Reactive planning AC and DC systems are explored thoroughly from a planning standpoint.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 554**Power System Relaying**

Principles of relay protection for faults on transmission lines and in transformers, rotating machines and other equipment. Use of over current, differential, distance, wire-pilot, carrier-pilot and microwave-pilot relaying systems. Solid-state relays and computer control of relaying. Determination of short-circuit currents and voltages from system studies.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 555**Power Market Operations**

Market Design in Restructured Power Systems, Short-term Load Forecasting, Electricity Price Forecasting, Price Based Unit Commitment, Arbitrage in Electricity Market, Market Power Analysis, Asset Valuation and Risk Analysis, Security Constrained Unit Commitment, Ancillary Services Auction Market Design, Power Transmission Pricing, Regional Transmission Organizations.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 556**Power Market Economics and Security**

This course covers simulation and scheduling tools used in restructured power system for studying the economics and security of power systems. Topics include modeling of generating units (thermal units, combined-cycle units, fuel-switching/blending units, hydro units, pumped-storage units, photovoltaic, wind), Lagrangian Relaxation-based scheduling, mixed integer programming-based scheduling, and Benders decomposition-based transmission security analyses. The simulation and scheduling tools consider different time scales including on-line security, day-ahead, operational planning, and long-term. The simulation and scheduling tools consider interdependency of supply (such as gas, water, renewable sources of energy) and electricity systems.

Prerequisite(s): ECE 420 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 557**Fault-Tolerant Power Systems**

Critical fault events in a large power system, sparsity techniques. Contingency screening process. Modeling of local controls in load flow. Adaptive localization method. Injection outage analysis. Security constrained dispatch. LP-based OPF. Real-time security analysis. Dynamic security analysis.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 558**Power System Reliability**

The concept of reliability, reliability indices, component reliability, generation capacity reserve evaluation, transmission system reliability, bulk power system reliability, distributed system reliability, reliability modeling in context.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 559**High Voltage Power Transmission**

Detailed analysis of transmission and distribution systems. Design of high voltage transmission lines and cables, as well as distribution lines. Flexible AC transmission Systems (FACTS) and high voltage DC links.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 560**Power Systems Dynamics and Stability**

The transient stability problem, acceleration equations, stability criteria, two-machine and multimachine problems. Perturbation analysis, eigenvalue sensitivity, Liapunov theory and application to power systems stability.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 561**Deregulated Power Systems**

Overview of key issues in electric utilities restructuring, Poolco model, bilateral contracts, market power, stranded costs, transmission pricing, electric utility markets in the United States and abroad, OASIS, tagging electricity transactions, electric energy trading, risk in electricity markets, hedging tools for managing risks, electricity pricing, volatility in power markets, and RTO.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 562**Power System Transaction Management**

Power interchange transaction management in the deregulated electric power industry. Course topics include: power system security assessment, total and available transfer capability (TTC/ATC), transaction management system (TMS), transaction information system (TIS), tagging calculator (IDC), congestion management, transmission loading relief (TLR).

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 563**Artificial Intelligence in Smart Grid**

Introduction to artificial intelligence, artificial neural networks, machine learning, and advanced engineering applications in smart grid, including but not limited to energy forecasting, smart meter data analytics, nonintrusive load monitoring.

Lecture: 3 Lab: 0 Credits: 3

ECE 564**Control and Operation of Electric Power Systems**

Unit commitment and application of dynamic programming, fuel budgeting and planning, probabilistic production cost modeling, hydrothermal coordination, power system security and application of expert systems, state estimation, optimal power flow, interchange evaluation and power pools, reactive power planning.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 565**Computer Vision and Image Processing**

Multidimensional sampling and discrete Fourier transform; Image segmentation; Object boundary (edge) detection and description; shape representation and extraction; Matching and recognition; Image registration; Camera geometry and stereo imaging; Morphological processing; Motion detection and compensation; Image modeling and transforms; Inverse problems in image processing (restoration and reconstruction).

Lecture: 3 Lab: 0 Credits: 3

ECE 566**Machine and Deep Learning**

Overview of machine learning and deep learning; principle of learning; Bayesian methods; non-parametric classifiers, Fisher's linear discriminant analysis, principal component analysis; training, validation, and testing; support vector machines; neural networks; history of deep learning; and applications of deep learning.

Lecture: 3 Lab: 0 Credits: 3

ECE 567**Statistical Signal Processing**

Detection theory and hypothesis testing. Introduction to estimation theory. Properties of estimators, Gauss-Markov theorem. Estimation of random variables: conditional mean estimates, linear minimum mean-square estimation, orthogonality principle, Wiener and Kalman filters. Adaptive filtering. LMS algorithm: properties and applications.

Prerequisite(s): (ECE 511 with min. grade of C and MATH 333 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 568**Digital Speech Processing**

Review of discrete statistical signal analysis. Acoustic aspects of speech and hearing. Digital models of speech production. Short-time processing in time and frequency domains. Waveform encoding and linear predictive coding of speech. Estimation of fundamental speech parameters. Applications including automatic speech recognition and enhancement.

Prerequisite(s): (ECE 437 with min. grade of C and ECE 511 with min. grade of C) or (ECE 511 with min. grade of C and Graduate standing)

Lecture: 3 Lab: 0 Credits: 3

ECE 569**Digital Signal Processing II**

Review of basic DSP theory. Design of digital filters: FIR, IIR, frequency-transformation methods, optimal methods. Discrete Fourier Transform (DFT) and Fast Fourier Transform algorithms. Spectral estimation techniques, classical and parametric techniques. AR, MA, ARMA models. Estimation algorithms. Levinson, Durbin-Levinson and Burg's algorithms. eigenanalysis algorithms for spectral estimation.

Lecture: 3 Lab: 0 Credits: 3

ECE 570**Fiber-Optic Communication Systems**

Physics of optical fiber, composition, dimensioning, coupling, attenuation, dispersion. Electro-optical conversion devices. (ILDs, LEDs, APDs, PINs). Circuit considerations. Modulation techniques and implications. Overall system considerations. Coherent techniques.

Prerequisite(s): ((ECE 312 with min. grade of C and ECE 307 with min. grade of C) or Graduate standing) and (ECE 403 with min. grade of C or Graduate standing)

Lecture: 3 Lab: 0 Credits: 3

ECE 571**Nanodevices and Technology**

Electronic properties and quantum effects. Dielectric, magnetic, and optical properties and their characterizations. Individual nanoparticles and clusters. Carbon nanotubes. Solid disordered nanostructures. Nanostructured crystals. Quantum wells, wires, and dots. Giant magnetoresistance. Material processing techniques. Devices and systems based on nanostructures. Must have successfully passed ECE 307 Electrodynamics or equivalent course.

Lecture: 3 Lab: 0 Credits: 3

ECE 572**Secure Machine Learning Design and Applications**

Adversarial robustness, which is centered on attack and defense, has become an emerging topic to promote trust in machine learning (ML)/deep learning (DL) and enable a better understanding of the pros and cons of DL systems. More generally, the idea of learning with adversaries is crucial for expanding the learning capability, ensuring trustworthy decision-making, and enhancing the generalizability of ML in many applications. This course teaches students how to adapt fundamental techniques of robustness evaluation and enhancement into different use cases of adversarial ML in computer vision, signal processing, and power system.

Lecture: 3 Lab: 0 Credits: 3

ECE 573**Cloud Computing and Cloud Native Systems**

This course introduces students to cloud native systems that build on top of the cloud computing architecture to provide scalable services in dynamic environments. Key topics covered include virtualization and containerization, distributed database systems, communication mechanisms, batch and stream processing, resource management, consensus, security, and system design techniques for scalability, resilience, manageability, and observability. Course projects will provide hand-on experiences on state-of-the-art languages, libraries, and tools. Students registering for graduate course section are required to complete additional project sections in advanced areas and review research papers in this field.

Lecture: 0 Lab: 3 Credits: 3

ECE 574**Data Science for Engineers**

This course offers an in-depth introduction to data science for real-world engineering applications. It covers foundational topics, including linear algebra and statistics, before transitioning into data preprocessing, visualization, and various machine learning methods. Practical application is emphasized, and students will gain hands-on experience using Python and data science libraries such as NumPy, Pandas, and Matplotlib. The course also includes advanced topics, such as supervised learning, dimension reduction, clustering methods, ensemble methods, and graph methods. The course places a strong emphasis on solutions for engineering problems. Differentiation and assessment between ECE 474 and ECE 574 are provided through the use of projects and case studies. Undergraduate students can only be admitted to ECE 474, while graduate students can only be admitted to ECE 574.

Lecture: 3 Lab: 3 Credits: 3

ECE 575**Electron Devices**

Electronic properties of solids. Properties of p-n junctions and junction devices. Gunn diode and IMPATT devices. Junction transistors. Schottky diode and MESFET. The MOS capacitor and MOSFET. Light-emitting diodes and junction lasers. Velocity modulation and bunching in electron beams. Klystrons, magnetrons and other microwave thermionic devices.

Prerequisite(s): (ECE 307 with min. grade of C and ECE 312 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 576**Antenna Theory**

Plane and spherical waves. Electric and magnetic dipoles. Radiation patterns and impedance characteristics of antennas in free space and over perfect ground. Linear and planar driven antenna arrays. Yagi-Uda parasitic arrays.

Prerequisite(s): ECE 307 with min. grade of C or ECE 421 with min. grade of C or ECE 423 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 578**Microwave Theory**

Microwave field theory. Propagation, reflection and refraction of plane waves. Anisotropic media. Impedance concept. Hollow, surface-wave and dielectric wave guides. Discontinuities in wave guides. Microwave resonators. Transmission lines. Microwave circuit theory.

Prerequisite(s): ECE 421 with min. grade of C or ECE 423 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 579**Operations and Planning and Distributed Power Grid**

The course is divided into four sub-components: current state of the distributed power grid, outlook for the distributed power grid, operation of the distributed power grid, and planning of the distributed power grid. This course will begin by providing an overview of existing distribution systems and smart grid technologies, such as distribution automation and advanced metering infrastructure (AMI). With the emerging trends in power industry, the course will next focus on trends driving the change and the future components of distributed power grid, including but not limited to distributed generation (DG) and energy storage systems (ESSs). The next part of the course will be focused on the operation and control strategies for distributed power grid systems, including operational constraints, voltage and var control (VVC), and control of DERs and Smart Inverters. The final topic area for the course will be planning of distributed power grid with DERs, including lectures on DER impacts and their assessments, hosting capacity, and microgrid operations.

Lecture: 3 Lab: 0 Credits: 3

ECE 580**Elements of Sustainable Energy**

This course covers cross-disciplinary subjects on sustainable energy that relate to energy generation, transmission, distribution, and delivery as well as theories, technologies, design, policies, and integration of sustainable energy. Topics include wind energy, solar energy, biomass, hydro, nuclear energy, and ocean energy. Focus will be on the integration of sustainable energy into the electric power grid, the impact of sustainable energy on electricity market operation, and the environmental impact of sustainable energy.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 581**Elements of Smart Grid**

This course covers cross-disciplinary subjects on smart grid that relates to energy generation, transmission, distribution, and delivery as well as theories, technologies, design, policies, and implementation of smart grid. Topics include: smart sensing, communication, and control in energy systems; advanced metering infrastructure; energy management in buildings and home automation; smart grid applications to plug-in vehicles and low-carbon transportation alternatives; cyber and physical security systems; microgrids and distributed energy resources; demand response and real-time pricing; and intelligent and outage management systems.

Lecture: 3 Lab: 0 Credits: 3

ECE 582**Microgrid Design and Operation**

Microgrids are the entities that are composed of at least one distributed energy resource and associated loads which not only operates safely and efficiently within the local power distribution network but also can form intentional islands in electrical distribution systems. This course covers the fundamentals of designing and operating microgrids including generation resources for microgrids, demand response for microgrids, protection of microgrids, reliability of microgrids, optimal operation and control of microgrids, regulation and policies pertaining to microgrids, interconnection for microgrids, power quality of microgrids, and microgrid test beds.

Prerequisite(s): ECE 418 with min. grade of C or ECE 419 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 583**High Speed Computer Arithmetic**

This course covers computer arithmetic as applied to general-purpose and application-specific processors. The focus is on developing high-speed arithmetic algorithms and understanding their implementation in VLSI technology at the gate level. Topics include fixed and floating point number systems, algorithms and implementations for addition, subtraction, multiplication, division, and square root, floating point operations, elementary function approximation, low-power design, error analysis, and interval arithmetic..

Prerequisite(s): ECE 446 with min. grade of C or ECE 485 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 584**VLSI Architecture for Signal Processing and Communication Systems**

This course aims to convey knowledge of advanced concepts in VLSI signal processing. Emphasis is on the architectural research, design and optimization of signal processing systems used in telecommunications, compression, encryption and coding applications. Topics covered include the principles of datapath design; FIR and IIR filtering architectures; communication systems including OFDM, multirate signal processing; fast transforms and algorithms including fast Fourier transform; discrete cosine transform; Walsh-Hadamard transform; and wavelet transform. Furthermore, advanced computer arithmetic methods including Galois fields, CORDIC, residue number systems, distributed arithmetic, canonic signed digit systems and reduced adder graph algorithms are examined.

Prerequisite(s): (ECE 429 with min. grade of C and ECE 437 with min. grade of C) or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 585**Computer Organization and Design**

This course provides the students with understanding of the fundamental concepts of computer architecture, organization, and design. It focuses on relationship between hardware and software and its influence on the instruction set and the underlying Central Processing Unit (CPU). The structural design of the CPU in terms of datapath and control unit is introduced. The technique of pipelining and hazard management are studied. Advanced topics include instruction level parallelism, memory hierarchy and cache operations, virtual memory, parallel processing, multiprocessors and hardware security. The end to end design of a typical computer system in terms of the major entities including CPU, cache, memory, disk, I/O, and bus with respect to cost/performance trade-offs is also covered. Differentiation between ECE 485 and ECE 585 is provided via use of projects / case studies at differing levels. (3-0-3)

Lecture: 3 Lab: 0 Credits: 3

ECE 586**Hardware Security and Advanced Computer Architectures**

This course focuses on designing computers and embedded computing devices from security and threat-mitigation perspectives. Advanced architecture topics such as instruction level parallelism, multi-threading and multi-instruction, multi-data stream processing are presented. Design for testability, hardware attacks, threat modeling and countermeasures against attacks are covered for the major entities for a computer system; including CPU, memory, and I/O. Case studies on recent examples of hardware security issues are discussed. * Students registering for this course should have a prior knowledge of Computer Organization and Design or equivalent course and be familiar with hardware description languages such as Verilog or VHDL.

Prerequisite(s): ECE 485 or Graduate standing or ECE 585 with min. grade of C

Lecture: 3 Lab: 0 Credits: 3

ECE 587**Hardware/Software Codesign**

Computer-aided techniques for the joint design of hardware and software: specification, analysis, simulation and synthesis. Hardware/software partitioning, distributed system cosynthesis, application-specific instruction set design, interface cosynthesis, timing analysis for real-time systems.

Prerequisite(s): ECE 441 with min. grade of C or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 588**Hardware Acceleration for Machine Learning**

Students will learn the design of complex and high-performance AI systems from system level to circuit level. Introduction to Deep Learning, deep neural network architecture, deep learning system: hardware and software in CPU, GPU, and FPGA. FPGA fundamentals, arithmetic hardware, CIM and PIM memory structure for AI, RTL programming and optimization, power consumption, design techniques for low power at system-level and RT-level.

Prerequisite(s): ECE 429 or ECE 529 or Graduate standing

Lecture: 3 Lab: 0 Credits: 3

ECE 589**Computer-Aided Design of Analog IC**

Analog IC design optimization algorithm such as equation-based optimization and simulation-based optimization algorithms, design automation tools such as harmonic balance, projection-based surface response estimation, shooting methods, etc. will be introduced. Research and mini-projects with emphasis on analog integrated circuit design and optimization algorithms using state-of-the-art tools are assigned to student groups.

Lecture: 3 Lab: 0 Credits: 3

ECE 590**Object-Oriented Programming and Machine Learning**

This course gives students a clear understanding of the fundamental concepts of object-oriented design/programming (OOD/OOP). Languages addressed include C++ and Python. Key topics covered include introduction to machine and deep learning, software development life cycle, core language and standard library of C++ and Python, class design and design patterns, OpenMP and CUDA platforms. Students will design a complex learning application using these concepts and Agile software engineering practices. Students are required to complete an open-ended project in one of the advanced areas, for example numerical optimization, tool integration, heterogeneous acceleration.

Lecture: 3 Lab: 0 Credits: 3

ECE 591**Research and Thesis for Masters Degree**

Credit: Variable

ECE 593**Masters Electrical and Computer Engineering Seminar**

Seminar course for Master students.

Lecture: 1 Lab: 0 Credits: 0

ECE 594**Special Projects**

Special projects.

Credit: Variable

ECE 597**Special Problems**

Credit: Variable

ECE 600**Continuation of Residence**

Lecture: 0 Lab: 0 Credits: 1

ECE 691**Research and Thesis for Ph.D.**

Corequisite(s): ECE 693

Credit: Variable

ECE 693**Graduate Research Seminar**

Seminar course for graduate students.

Corequisite(s): ECE 691

Lecture: 1 Lab: 0 Credits: 0

ECE 708**Technologies for Long-Term Evolution of Wireless Communications Networks**

The course discusses technologies used in long-term evolution (LTE) wireless communications systems. Fundamentals of multiple-input/multiple-output (MIMO) wireless communication systems and orthogonal frequency division modulation (OFDM) are covered. Transmission diversity concepts and principles of space-time coding are introduced. The fundamentals of space-time block and trellis coded modulation (STBCM and STTCM) are introduced along with performance analysis, code design, and simulation results. A comparison of various design techniques in different propagation environments is presented. Applications to MIMO/OFDM systems are discussed.

Prerequisite(s): ECE 513 with min. grade of C

Lecture: 2 Lab: 0 Credits: 2

ECE 718**Radio Access Technologies for 5G and Beyond**

The course introduces new radio access network (RAN) technologies and study the theoretical principles underlying the 5G new radio (NR) proposals. The course discusses the fundamentals by which channel coding and new non-orthogonal multiple access (NOMA) techniques improve throughput and reliability; and examine the current research trends and applications with emphasis on the practical implementation of 5G PHYS layer architecture. The main thrust of this course is to study designs that allow multi-user capabilities with interference, bandwidth and energy constraints. Transformations that allow transmission of multiple users and their embedded structures, will be considered. Modulation formats and access techniques that are bandwidth-energy efficient need to be considered. These new designs are studied, generalized and evaluated in different channels and interference conditions. This course has both theoretical and practical goals.

Lecture: 2 Lab: 0 Credits: 2

ECE 719**Theory and Applications of Linear Optimization in Wireless Networks**

This short course covers both the fundamental of linear optimization and applications in wireless networking research, emphasizing not only the optimization methodology but also the underlying mathematical structures. In addition to the fundamental contents of simplex method, duality theory, and network flow problems, this course also covers the integer programming techniques. This course discusses the applications of linear optimization in the wireless network, including wireless mesh networks, multi-radio multi-channel networks, and cognitive radio networks.

Prerequisite(s): (ECE 407 with min. grade of C or ECE 408 with min. grade of C) and MATH 477 with min. grade of C

Lecture: 2 Lab: 0 Credits: 2

ECE 721**Introduction to Wireless Cooperative Communications and Applications**

The course gives an introduction to wireless cooperative communication networks from the perspective of the channel and physical layer. It discusses cooperative networks protocols and application of these. It will deal with wireless channels and relay networks. Transparent and regenerative physical layer algorithms will be discussed to facilitate the analysis of different architectures. Use of distributed space time codes, multiplexing, and orthogonal frequency division multiplexing will be analyzed to achieve multi-dimensional diversity (path, frequency, and time), reduced interference, and improved QoS.

Prerequisite(s): ECE 403 with min. grade of C

Lecture: 2 Lab: 0 Credits: 2

ECE 735**Cellular Long Term Evolution**

Cellular Long Term Evolution (LTE) is a key wireless broadband technology considered as the primary path towards the next generation networks (NGNs). It is generally considered as the dominant wireless technology meeting the seamless, mobile Internet access needs of the upcoming Quadruple Play applications. This short course covers the applications, requirements, architecture, radios and antennas, protocols, network operations and management, and evolution for the LTE technology. Key topics include the functions and interfaces of the protocol layers, Quality of Service (QoS), security, network signaling, infrastructure, user equipment, spectrum, throughput, and coverage. Discussion includes the modulation schemes, frame structure, antenna and radio, and subcarrier and bandwidth allocation methods. End-to-end scenarios on connection setup, interworking with existing 3G cellular, WiFi, and WiMAX networks, and handovers are discussed. Testing and integration issues, limitations, and challenges are also mentioned. Comparative analysis with respect to WiMAX and ultra mobile broadband (UMB) are covered. The likely migration paths from current wireless and wireline networks to LTE and related HSOPA and SAE architectures are discussed.

Lecture: 1 Lab: 0 Credits: 1

ECE 738**Information Technology**

Probability and Random Process Information theory addresses information theoretic limits on data compression and reliable data communications in the presence of noise. It has fundamental contribution in communications, networking, statistical physics, computer science, statistical inference, and probability and statistics. It covers entropy, mutual information, fundamental limits on data compression, Huffman codes, channel capacity, and channel coding.

Lecture: 2 Lab: 0 Credits: 2

ECE 739**Introduction to Digital Transformation Architecture and Technologies**

This project oriented short course equips the students with the architectural and technological foundation for the upcoming advanced and intelligent applications including smart city, smart energy, smart transportation, and smart health. The digital transformation architecture will be introduced. Key enabling technologies including Internet of Things (IoT), distributed data management and analytics, ubiquitous wireless access, Artificial Intelligence (AI) percepts especially computer vision and machine learning, and cyber security will be highlighted. Leveraging of datasphere which extends across user devices, edge/fog computing, and cloud computing will be addressed. The topics of how various hardware and software constituents interact to provide application solutions will be covered. Specific case studies summarizing the architectures for e-Health and intelligent transportation including autonomous automobile will be discussed. The course requires graduate standing.

Lecture: 2 Lab: 0 Credits: 2

ECE 740**Telecommunication Networks: Requirements to Deployment**

The ever-increasing customer demand for new and advanced services and the associated complexities of designing, deploying, optimizing, and managing telecom networks require advanced end to end technology and process expertise. This short course deals with the key concepts of requirements development, design processes, architecture finalization, system design, site testing, performance optimization, and network operations and management of current and upcoming Telecom networks. It provides an overview on how the process works from an idea or concept to productization and will give a view on associated complexities and challenges. Key advances in tools and techniques needed with these major steps are covered. Practical examples of the current and upcoming features which will make telecom networks competitive are addressed. Aspects of customer management, strategies for decision making, and the migration towards future networks are also addressed. Practical examples of networks of selected service providers and how they meet the local and global needs are mentioned.

Lecture: 2 Lab: 0 Credits: 2

ECE 742**Digital System-on-Chip Design**

This short course covers digital design techniques and hardware/software realization concepts in embedded computing systems using VHDL. Topics include: basics principles of VHDL programming; designing with FPGA; design of arithmetic logic unit; VHDL models for memories and busses; CPU design; system-on-chip design; efficient hardware realizations of FFT, DCT, and DWT.

Lecture: 2 Lab: 0 Credits: 2

ECE 743**Signal and Data Compression with Embedded Systems**

This short course deals with data compression techniques and hardware/software realization concepts in embedded computing systems. Key topics: fundamentals of random signal processing and information theory, compression and decompression processes, lossy and lossless compression methods, compression standards for video and audio, modeling and signal parameter estimation, transform techniques including FFT, DCT, and DWT. Hardware realizations of compression algorithms.

Lecture: 2 Lab: 0 Credits: 2

ECE 744**Embedded Digital Systems for Time-Frequency Distribution, Signal Modeling, and Estimation**

This short course deals with time-frequency distribution, signal modeling and estimation, and hardware/software realization concepts in embedded computing systems. Key topics include fundamentals of signal processing and random processes, short-time Fourier transform, split-spectrum processing, Gabor transform, Wigner distribution, Hilbert transform, wavelet transform, cosine transform, chirplet signal decomposition, matching pursuit, parametric time-series frequency estimation, hardware/software codesign and realizations of time-frequency distributions, and signal modeling algorithms.

Lecture: 2 Lab: 0 Credits: 2

ECE 750**Synchrophasors for Power System Monitoring and Control**

The course gives an introduction to synchrophasor technology from the perspective of power system monitoring and control. It discusses the fundamentals of measurements and synchrophasor estimation. It covers the IEEE Standard C37.118. Several synchrophasor estimation algorithms will be discussed as they relate to measurement and estimation errors. Various synchrophasor applications will be presented including situational awareness, event detection, model validation, oscillation detection, WAMS, and WAMPAC.

Prerequisite(s): ECE 419 with min. grade of C

Lecture: 2 Lab: 0 Credits: 2

ECE 752**Industrial Applications of Power Electronics and Motor Drives**

Practical topologies of different types of power electronic converters are covered including industrial high-voltage and high-current applications, protection, and thermal management. Common industrial motor drives are examined with popular control techniques, simplified modeling, and worst-case design. Regulating and stabilizing methods are applied to switching power supplies, power conditioning systems, electronic ballasts, and electronic motors.

Lecture: 2 Lab: 0 Credits: 2

ECE 755**Power System Protection**

This course provides basic understanding of the role of protective relaying in the power system. It also delves into the needs of today's power systems for protection that is robust and tolerant to heavily loaded transmission systems. The students are challenged to be a part of the solution going forward including the role of wide area system protection.

Lecture: 2 Lab: 0 Credits: 2

ECE 756**Power System Maintenance Scheduling**

This short course is aimed at providing an in-depth introduction to optimal generation and transmission maintenance in the regulated and restructured power systems. The basic principles of systems operation and economics related to maintenance scheduling will be discussed along with current practices and solution methods for the electric power industry.

Prerequisite(s): ECE 420 with min. grade of C and ECE 419 with min. grade of C

Lecture: 2 Lab: 0 Credits: 2

ECE 764**Vehicular Power Systems**

Conventional electrical power systems of land, sea, air, and space vehicles are detailed along with the scope for improvement. This course covers fundamental attributes of modern EV and HEV powertrains. Fundamentals of power electronic components (Inverters, DC-DC Converters, and Chargers), electric motors and energy storage systems will be presented in the context of EV powertrains. An introduction to EV/HEV operating strategies, battery chargers and controls will also be discussed. Using a combination of power electronic simulations, finite element analysis, hands-on lab experiments and vehicle benchmarking reports, powertrain configurations of popular EV and HEV powertrain components will be analyzed. State of the art, challenges and future trends will be discussed. Low voltage and high voltage systems and advanced distribution system architectures of electric and hybrid electric vehicles will be included. Current trends in the vehicular industry, such as 48V automotive systems and more electric aircraft, will be explained.

Lecture: 2 Lab: 0 Credits: 2

ENGR 502**Medical Device Regulations and Commercialization**

This course helps prepare students for commercializing medical devices within a highly-regulated environment. Concepts include protecting intellectual property, the structure and scope of the Federal Drug Administration (FDA), developing, testing, producing and marketing medical devices under FDA regulations, total product lifecycle, and quality management.

Lecture: 3 Lab: 0 Credits: 3

ENGR 510**Strategic Engineering Management**

This course will review technology-based enterprises and the driving forces that impact corporate strategy. Students will learn how to apply engineering knowledge to determine technology/product direction and make/buy/partnering decisions. Relationships between research and development, operations, finance, marketing, and other functions within engineering-based organizations that drive strategic decisions will be examined. Strategy development and competitive analysis will be included. Case studies from the industry relevant to the student's engineering track will be reviewed.

Lecture: 3 Lab: 0 Credits: 3

ENGR 520**Best Practices in Engineering Project Management**

Many engineering projects suffer due to weak business cases, schedule slippages, and cost overruns. This course presents commonly used tools and techniques and best practices to build an effective business case, develop a realistic schedule and budget, and successfully execute and complete a project. Students are introduced to a generic project management life cycle model, review basic project management principles, tools, and techniques, and learn engineering-tailored best practices used by high performing, project-centric organizations. Students have an opportunity to apply selected tools in the form of short classroom exercises.

Lecture: 3 Lab: 0 Credits: 3

ENGR 521**Risk Management in Engineering Projects**

In project management, a risk is considered an uncertain event that may have a positive or a negative impact on project objectives. Managing identified threats individually through customized strategies is key to project success. Similarly, opportunities must be leveraged for better project outcomes. Implementation of an effective risk management process is imperative for today's complex projects. This course presents a five-step process to manage project threats as well as opportunities. On every project, students will be able to identify and analyze risks and develop response strategies for each identified risk and take proper response action to manage the risks. Industry best practices and quantitative tools and simulations are used to analyze risk.

Lecture: 3 Lab: 0 Credits: 3

ENGR 531**Urban Systems Engineering Design**

ENGR 531 is a project-based course where students will explore integrated designs of urban systems. Each project will apply the students' engineering disciplines (such as structures, transportation, building science, construction engineering and management, environmental engineering) in a comprehensive analysis that considers the economic, human, and environmental issues associated with the project.

Lecture: 3 Lab: 0 Credits: 3

ENGR 532**Urban Systems Engineering Seminar**

ENGR 532 is an active seminar course that emphasizes current topics in urban systems engineering. Invited speakers will include researchers and representatives from current practice, such as municipal and regional planners and consultants. Appropriate readings will be assigned in advance of each speaker to guide students in preparation for active discussion with each speaker. Each student will also write a term paper on an urban systems engineering topic of their choice, connecting material from the assigned reading, the speakers, and additional references selected by the student.

Lecture: 3 Lab: 0 Credits: 3

ENGR 534**Product Design and Innovation**

This course covers all aspects of planning new products or services that are commercially viable and add to a company's suite of offerings. It includes such topics as user research, market analysis, need/problem identification, creative thinking, ideation, conceptualizing, competitive benchmarking, human factors, prototyping, evaluation, and testing. The course includes creative, analytical, and technical skills in a balanced approach using such teaching methods as case studies, individual exercises, and group projects.

Lecture: 3 Lab: 0 Credits: 3

ENGR 539**Robotic Motion Planning**

Configuration space. Path planning techniques including potential field functions, roadmaps, cell decomposition, and sampling-based algorithms. Kalman filtering. Probabilistic localization techniques using Bayesian methods. Trajectory planning.

Lecture: 3 Lab: 0 Credits: 3

ENGR 572**Construction Cost Accounting and Control**

Review of basic accounting principles and techniques – purchasing, accounts payable, invoicing, accounts receivable, general ledger, payrolls, and indirect costs. Job costing and budgeting. Recording and reporting procedures in construction projects – invoices, subcontractor applications for payment, labor time cards, unit completion reports, change orders. Cost coding systems for construction activities. Variance reporting procedures. Project closeout. Class exercise using computer program.

Lecture: 3 Lab: 0 Credits: 3

ENGR 573**Construction Contract Administration**

Characteristics of the construction industry. Project delivery systems. Duties and liabilities of the parties at the pre-contract stage. Bidding. Contract administration including duties and liabilities of the parties regarding payments, retainage, substantial and final completion, scheduling and time extensions, change orders, changed conditions, suspension of work, contract termination, and resolution of disputes. Contract bonds. Managing the construction company. Labor law and labor relations.

Lecture: 3 Lab: 0 Credits: 3

ENGR 574**Economic Decision Analysis in Civil Engineering**

Basic economic concepts including interest calculations, economic comparison of alternatives, replacement decisions, depreciation and depletion, tax considerations, and sensitivity analysis. Evaluation of public projects, the effect of inflation, decision making under risk and/or uncertainty, economic decision models. Case studies from the construction industry.

Lecture: 3 Lab: 0 Credits: 3

ENGR 575**Systems Analysis in Engineering**

Management and system concepts, linear programming, graphical methods, Simplex, two-phase Simplex, the transportation problem, the assignment problem, integer programming, and sensitivity analysis. System modeling by activity networks; maximal-flow, longest-path and shortest-path analyses, flow graphs, decision-tree analysis, stochastic-network modeling, queuing systems, and analysis of inventory systems. Case studies from the construction industry.

Lecture: 3 Lab: 0 Credits: 3

ENGR 576**Nano Manufacturing**

This course covers the general methods used for micro- and nano-fabrication and assembly, including photolithography techniques, physical and chemical deposition methods, masking, etching, and bulk micromachining as well as self-assembly techniques. It also covers nanotubes, nanowires, nanoparticles, and the devices that use them, including both electronic and mechanical-electronic systems, as well as nano-structural materials and composites. Focus is on commercially available current processes as well as emerging technologies and evolving research areas. Sensing and instrumentation as well as nano-positioning and actuation are covered briefly.

Lecture: 3 Lab: 0 Credits: 3

ENGR 587**Introduction to Digital Manufacturing**

This course is about the digital revolution taking place in the world of manufacturing and how students, workers, managers, and business owners can benefit from the sweeping technological changes taking place. It is about the change from paper-based processes to digital-based processes all through the design/manufacturing/deliver enterprise, and across the global supply chain. It touches on digital design, digital manufacturing engineering, digital production, digital quality assurance, and digital contracting, from large companies to small. There is also a significant focus on cyber security and the new types of threats that manufacturers face in the new digital world. Other topics covered include intelligent machines, connectivity, the digital thread, big data, and the Industrial Internet of Things (IIoT).

Lecture: 3 Lab: 0 Credits: 3

ENGR 588**Additive Manufacturing**

This course examines the fundamentals of a variety of additive manufacturing processes as well as design for additive manufacturing, materials available, and properties and limitations of materials and designs. It also examines the economics of additive manufacturing as compared to traditional subtractive manufacturing and other traditional techniques. Additive techniques discussed include 3D printing, selective laser sintering, stereo lithography, multi-jet modeling, laminated object manufacturing, and others. Advantages and limitations of all current additive technologies are examined as well as criteria for process selection. Processes for metals, polymers, and ceramics are covered. Other topics include software tools and connections between design and production, direct tooling, and direct manufacturing. Current research trends are discussed.

Lecture: 3 Lab: 0 Credits: 3

ENGR 592**Engineering Management Capstone Experience**

Students apply the knowledge they have acquired in the Engineering Management program to a specific problem or case study. Projects will be identified and mentored in conjunction with faculty and industrial partners. A final report or business plan is required that reflects the focus of the capstone project.

Lecture: 3 Lab: 0 Credits: 3

ENGR 595**Product Development for Entrepreneurs**

Elements of product development (mechanical and electrical), manufacturing and production planning, supply chain, marketing, product research, and entrepreneurship concepts are taught in this class. In this course, student teams will be required to create a compelling product that has potential to be sold in today's marketplace. They will be required to create functional prototypes of their product for people to use and critique. If successful, students will be allowed to put their product on Kickstarter.com and take orders for delivery after the class is complete while potentially fostering their own business as a result of this course.

Lecture: 3 Lab: 0 Credits: 3

ENGR 596**Practical Engineering Training**

This course is a mentored, immersive practical engineering training. Students learn under the direction of professional engineers and practicing engineers by working on real engineering projects. The student will perform hands-on engineering, including learning and developing/applying engineering principles and concepts to complete the project assigned to the student. The student will apply engineering ethics and safety during their practical engineering training. Students will communicate the results of their work in written and oral communications. Students will receive assignments of varying complexity consistent with their graduate standing.

Lecture: 0 Lab: 9 Credits: 3

ENGR 598

Graduate Research Immersion: Team Project

This course provides a faculty-mentored immersive team-based research experience. Research topics are determined by the faculty mentor's area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.

Lecture: 3 Lab: 0 Credits: 3

ENGR 599

Graduate Research Immersion: Individual

This course provides a faculty-mentored immersive research experience. Research topics are determined by the faculty mentor's area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.

Lecture: 3 Lab: 0 Credits: 3