Electrical and Computer Engineering

Overview

Mission Statement
The mission of the Department is to motivate and inspire students by providing high-caliber, fully integrated programs in electrical and computer engineering. These programs prepare graduates to provide leadership in a rapidly evolving global information society and to serve the greater good. The programs are also designed to allow students to advance the state of knowledge in our disciplines by actively pursuing scholarly research for publication and dissemination.

Educational Objectives
The objectives of the electrical and computer engineering undergraduate program of study are to educate students in the principles of engineering, as well as ensure awareness of their social responsibilities. The engineering education is based on the sciences and the principles of design. A balanced program in the humanities and social sciences as well as coverage of specific topics in professional ethics and social responsibilities, further instills a sense of social responsibilities. The programs provide students with a solid foundation in electrical and computer engineering through a balanced curriculum integrating the underlying scientific and mathematical knowledge with the latest technological developments. The curriculum is designed to produce engineers capable of functioning in the present technological environment and of adapting to future directions of the profession. Specifically, the programs aim to teach students how to analyze and implement complex interdisciplinary engineering projects; to give students a strong foundation for graduate studies in their field; to prepare students for competitive and challenging industrial applications; to teach students how to use state-of-the-art computer tools for solving engineering problems; to expose students to hands-on engineering experience through laboratory courses; to cultivate students’ abilities to communicate and work effectively in teams; and to help students develop an understanding of the ethical issues and global perspectives arising in the practice of the engineering profession.

Educational Outcomes
The Department of Electrical and Computer Engineering aims to produce graduates who will have the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, as well as professional and ethical responsibility; and a recognition of the need for, and an ability to engage in life-long learning.

Graduates will also have the ability to:
- Design and conduct experiments, as well as analyze and interpret data
- Design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- Function on multidisciplinary teams
- Identify, formulate, and solve engineering problems
- Communicate effectively
- Use the techniques, skills, and modern engineering tools necessary for engineering practice.

Undergraduate

Bachelor's programs
- Bachelor of Science with a major in computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/bs-computer-engineering)
- Bachelor of Science with a major in electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/bs-electrical-engineering)

Graduate

Master's programs
- Master of Science in the field of computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/computer-engineering)
- Master of Science in the field of electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/electrical-engineering)
- Master of Science in the field of telecommunications engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/telecommunications-engineering)

Professional programs
See the School of Engineering and Applied Science for programs leading to the professional degree.

Doctoral programs
See the School of Engineering and Applied Science for programs leading to the doctoral degree.

Certificates
- Graduate certificate in high-performance computing (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/certificate-high-performance-computing)

Faculty

Professors S. Ahmadi (Teaching), L. Bennett (Research), R.L. Carroll, K.B. Eom, T. El-Ghazawi, R.J. Harrington, H.J. Helgert, E. Della Torre, C.E. Korman, N. Kyriakopoulos, R.H. Lang, M.H.
Loew (Courtesy), Jr., S. Subramaniam, B. Vojcic, W. Wasylikowski, M.E. Zaghloul,

**Associate Professors** M. Doroslovakic, H.H. Huang, M.W. Kay, G.P. Venkataramani, J.M. Zara, V. Zderic

**Assistant Professors** A. Etemadi, T. Lan, E. Simsek, V. Sorger

**Professorial Lecturers** A. Mehrotra, D. Nagel, S.A. Torrico

## COURSES

### Explanation of Course Numbers

- Courses in the 1000s are primarily introductory undergraduate courses
- Those in the 2000–4000s are upper-division undergraduate courses that can also be taken for graduate credit with permission and additional work
- Those in the 6000s and 8000s are for master’s, doctoral, and professional-level students
- The 6000s are open to advanced undergraduate students with approval of the instructor and the dean or advising office

### ECE 1010. Introduction to Electrical, Computer, and Biomedical Engineering. 1 Credit.

Basic and emerging concepts in electrical, computer, and biomedical engineering. Hands-on experiments and projects. Introduction to the professional literature and available resources and to technical writing, speaking, and presentation skills.

### ECE 1020. Introduction to Electrical, Computer, and Biomedical Engineering. 1 Credit.

Continuation of ECE 1010. Basic and emerging concepts in electrical, computer, and biomedical engineering. Hands-on experiments and projects. Introduction to the professional literature and available resources and to technical writing, speaking, and presentation skills.

### ECE 1120. C Programming for ECE. 3 Credits.

Basic programming concepts including algorithmic thinking and structured programming, control flow, data types, pointers, functions, algorithms, I/Os, threads, and performance evaluation and optimization. Concurrency and multicore programming using threads, processes as well as parallel C programming paradigms. Controlling hardware devices and fine control via interfacing with assembly language.

### ECE 1125. Data Structures & Algorithms ECE. 3 Credits.

Fundamentals of algorithms and data structures for electrical and computer engineering. Topics include techniques to solve problems through programming in C/C++ languages, linked lists, stacks, queues and trees; searching methods such as binary trees, hashing, and multi-way trees; design and analysis of algorithms and their space and time complexity. (Fall).

### ECE 2110. Circuit Theory. 4 Credits.

Lecture (3 hours), laboratory (3 hours). Circuit elements, techniques of circuit analysis; circuit theorems; operational amplifiers; RLC circuits; natural and step responses; series, parallel and resonant circuits; sinusoidal steady-state analysis; phasers; power calculations; transformers; two-port circuits. CAD tools used in circuit projects. Corequisite: APSC 2113, PHYS 1022.

### ECE 2115. Engineering Electronics. 4 Credits.

Lecture (3 hours), laboratory (3 hours). Solid-state devices used in electronic engineering. Physics of their operation. Application to electronic circuits. Primary emphasis on application of these elements in power supplies and in linear amplifiers. Design concepts through use of SPICE and graphical techniques. Prerequisite: ECE 2110.

### ECE 2120. Engineering Seminar. 0-1 Credits.

This seminar course provides electrical and computer engineering students with a detailed view of the electrical and computer engineering professions. Speakers from within and outside of the department discuss facets of ECE, engineering education, and other important department, college, or university topics of interest. (Fall).

### ECE 2140. Design of Logic Systems I. 4 Credits.

Lecture (3 hours), laboratory (3 hours). Boolean algebra; combinational and sequential circuits; minimization techniques; design-and-build logic subsystems, such as decoders, multiplexers, adders, and multipliers; use of CAD tools. Corequisite: ECE 2115.

### ECE 2210. Circuits, Signals, and Systems. 3 Credits.

Circuit analysis using Laplace transforms; transfer functions; poles and zeros; Bode diagrams; effects of feedback on circuits; convolution; Fourier series and Fourier transforms; design of filters; CAD tools used in design of projects. Prerequisite: ECE 2110.

### ECE 3125. Analog Electronics Design. 4 Credits.

Design, testing, and measurement of analog electronic circuits. Differential and multistage amplifiers. Output stages and power amplifiers. Frequency response of amplifiers, high-frequency models of FETs and BJTs. Introduction to feedback circuit topologies. Use of electronic CAD tools, such as P-SPICE. Prerequisite: ECE 2115.

### ECE 3130. Digital Electronics and Design. 4 Credits.

Lecture (3 hours), laboratory (3 hours). Design and testing of logic gates, regenerative logic circuits, and semiconductor memory circuits. Implementation of such circuits with NMOS, CMOS, TTL, and other integrated circuit technologies. Use of electronic CAD tools, such as SPICE. Prerequisite: ECE 2140.

### ECE 3135. Design of Logic Systems II. 4 Credits.

Lecture (3 hours), laboratory (3 hours). Introduction of ASIC design techniques; design and programming of FPGAs using CAD tools; timing in sequential circuits; essential hazards; races in sequential circuits; design-and-build FPGA project. Prerequisite: ECE 2140.
ECE 3220. Intro to Digital Signal Proces. 3 Credits.
Signal representation, sampling and quantization, discrete-time signals, z-transforms and spectra, difference equations. Fourier analysis. Discrete Fourier transform, IIR and FIR filter design. Prerequisite: ECE 2210.

ECE 3225. Signal and Image Analysis. 3 Credits.
Introduction and clinical applications; characteristics of biomedical problems, time- and frequency-domain techniques for signal feature analysis; spectral estimation and analysis; autoregressive modeling; detection and estimation of periodicity; digital images as two-dimensional signals; 2-D Fourier transform. Corequisite: ECE 2210, ApSc 3115.

ECE 3310. Introduction to Electromagnetics. 3 Credits.
Maxwell’s equations, pulse propagation in one dimension, transmission line equations, reflection coefficient, capacitance and inductance calculations, Smith chart, plane waves, reflection from a dielectric of fiber and integrated optics. Prerequisite: APSC 2113; PHYS 1022.

ECE 3315. Fields and Waves I. 3 Credits.
Complex phasor notation, uniform transmission lines, standing wave ratio, power, reflection coefficient, impedance matching. Review of vector analysis and numerical methods. Electrostatics, generalizations of Coulomb’s law, Gauss’s law, potential, conductors, dielectrics, capacitance, energy. Prerequisite: APSC 2113; PHYS 1022.

ECE 3410. Communications Engineering. 3 Credits.

ECE 3415. Introduction to Computer Networks. 3 Credits.

ECE 3420. Communications Laboratory. 1 Credit.

ECE 3425. Data Communications Laboratory. 1 Credit.
Experiments in support of the analysis and design of communications systems with emphasis on network protocols. Time and frequency division multiplexing, flow control, automatic repeat request, interfacing, token ring, token bus, multiple access for Ethernet, routing, packet switching. Prerequisite or corequisite: ECE 3415.

ECE 3515. Computer Organization. 3 Credits.
Structure and operation of a digital computer. Design of computer arithmetic units, data and instruction paths. Microprogramming; memory technology; virtual memory; caches; pipelined computer organization; characteristics of secondary storage; I/O interfacing. May be taken for graduate credit. Prerequisites: ECE 3135; corequisite: ECE 3525. (Spring).

ECE 3520. Microprocessors: Software, Hardware, and Interfacing. 3 Credits.
Microprocessor architecture, assembly language, address decoding, hardware interrupt, parallel and serial interfacing with various circuits, timer/counters, direct memory access, microprocessor-based system. Hands-on laboratory experience is an integral part of this course. Prerequisite: ECE 2140.

ECE 3525. Introduction to Embedded Systems. 3 Credits.
Microcontrollers and their application in embedded systems. Topics include assembly and C for microcontroller programming, serial and parallel I/O interfacing, and multimedia interfacing. Students perform laboratory experiments and a final project to develop a microcontroller-based embedded system. Prerequisite: CSCI 1121, ECE 3520.

ECE 3530. Introduction to Parallel and Distributed Computer Systems. 3 Credits.

ECE 3915W. Electrical, Computer, and Biomedical Engineering Capstone Project Lab I. 1 Credit.
ECE 3915, ECE 4920, and ECE 4925 are taken in sequence by departmental majors beginning in the second semester of the junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project.

ECE 4140. VLSI Design and Simulation. 3 Credits.
Study of VLSI circuit design including PMOS and NMOS transistor analysis, switch and gate logic design, understanding of semiconductor fabrication processes and design rules, CAD system, speed and power considerations, scaling of transistors to the nano-scale, and designing with highly variable process parameters. Each student will design a VLSI chip, simulate the design and submit a GDS II file for chip fabrication. Prerequisites: ECE 3130, ECE 3135. Same as ECE 6240.

ECE 4145. Micro & Nano Fabrication Tech. 3 Credits.
Modern process technologies associated with various types of processing. Silicon fabrication process, micro- and nanofabrications. Limitation at nano-scale, and other available technologies. Alternatives approach. May be taken for graduate credit.
ECE 4150. ASIC Design and Testing of VLSI Circuits. 3 Credits.
ASIC and mixed-signal design methodology, use of ASIC design CAD tools. Logic synthesis, styles of synthesis, power/area/speed constraints. VLSI testing, fault models, design for testability techniques, scan path, built-in self-test. Testing of chips designed in ECE 4140 and of nano-scale circuits. May be taken for graduate credit. Prerequisite: ECE 4140.

ECE 4155. Modern Measurements and Sensors. 3 Credits.
Measurement of dc, ac, and high-frequency signals. Interface electronic circuits. Sensors for measurement of mechanical, optical, magnetic, electromagnetic, thermal, chemical, and biochemical signals. Prerequisite: ECE 4320, ECE 3125, ECE 2140. May be taken for graduate credit.

ECE 4160. Introduction to Nano-electronics. 3 Credits.
Technology development beyond CMOS; trends in nanofabrication and nano-metrology. Current flow in 1-D, 2-D, and 3-D electronic structures and their energy levels. Nanostructures such as nano-wire (Silicon or other material), Carbon Nano Tube (CNT), and Graphene. Nano-scale transistors. May be taken for graduate credit. Prerequisites: ECE 2115. (Fall).

ECE 4320. Fields and Waves II. 3 Credits.
Magnetostationary fields, Lorentz force torques, Biot-Savart law, Ampere’s law, magnetic materials, inductance, energy. Maxwell’s equations, Faraday’s law, charge–current continuity, vector potential. Time-harmonic fields, plane waves, polarization, skin effect, dielectric boundaries, and fiber optics. Radiation, dipole, gain, effective area. Prerequisite: ECE 2114, ECE 3315.

ECE 4325. Microwave and Optics Laboratory. 1 Credit.
Experiments in transmission lines, network analyzer measurements of scattering parameters, microwave systems, fiber-optic systems and antennas. Introduction to the characteristics of laser and optical systems. Prerequisite: ECE 4320.

ECE 4435. Fiber Optical Communications. 3 Credits.

ECE 4535. Computer Architecture and Design. 3 Credits.
Design of bus-based digital computer systems, memory subsystems, caches, and multiple processors. Comparison of RISC and CISC processors and standard buses. Bus transfer and control signals. Performance, memory management, architectural support for protection, task switching, exception handling, instruction pipelines. Prerequisite: ECE 3515.

ECE 4610. Electrical Energy Conversion. 3 Credits.
Three-phase and single-phase AC rotating machines and transformers, DC machines, rotating machines as circuit elements, power semiconductor converters. Renewable generation, utility grid integration, smart grid applications. May be taken for graduate credit by students in fields other than electrical engineering. Prerequisite: ECE 2210, ECE 3315.

ECE 4615. Electrical Power Laboratory. 1 Credit.
Experiments in support of the analysis and design of electrical power systems. Measurements of the characteristics of devices to generate electric power. Rectification and inverter processes for power systems and drives. Prerequisite or corequisite: ECE 4610.

ECE 4620. Electrical Power Systems. 3 Credits.
AC power grids, transmission line parameters, load flow, economic dispatch voltage, frequency and power flow control. Voltage, current and power limitations. Fault analysis and stability considerations. Effect of independent power producers and variable energy sources and energy storage. (Same as ECE 6620) (Fall).

ECE 4710. Control Systems Design. 3 Credits.
Mathematical models of linear systems; steady-state and transient analyses; root locus and frequency response methods; synthesis of linear feedback control systems. Prerequisite: APSC 2114, ECE 2210 or MAE 3134.

ECE 4715. Control Systems Laboratory. 1 Credit.
Experiments in support of control theory, involving the use of the digital computer for process control in real time. Design of feedback and compensation with computer implementation. Digital simulation of linear and nonlinear systems. Prerequisite or corequisite: ECE 4710.

ECE 4730. Robotic Systems. 3 Credits.

ECE 4735. Robotics Laboratory. 1 Credit.
Experiments illustrating basic principles and programming of robots and other automated machinery. Design and writing of computer programs to use a robot’s arm, vision, and data files to accomplish tasks. Prerequisite or corequisite: ECE 4730/MAE 3197.

ECE 4920W. Electrical, Computer, and Biomedical Engineering Capstone Project Lab II. 3 Credits.
ECE 3915, ECE 4920, and ECE 4925 are taken in sequence by departmental majors beginning in the second semester of the junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project.
ECE 4925W. Electrical, Computer, and Biomedical Engineering Capstone Project Lab III. 2 Credits.  
ECE 3915, ECE 4920, and ECE 4925 are taken in sequence by departmental majors beginning in the second semester of the junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project.

ECE 4980. Special Topics. 1-3 Credits.  
Topic to be announced in the Schedule of Classes. (Fall and spring).

ECE 4990. Research. 1-3 Credits.  
Applied research and experimentation projects, as arranged. Prerequisite: junior or senior status.

ECE 6005. Microcomputer Systems Architecture. 3 Credits.  
Advanced microprocessor-based systems CISC and RISC. Buses, timing, and system interface protocols. Advanced memory designs. Multilevel cache designs. Architectural support for memory management, protection, task switching, and exception handling. Multiprocessor systems. Prerequisite: ECE 3515.

ECE 6010. Linear Systems Theory. 3 Credits.  
Introduction to linear systems theory. Topics include linear vector spaces and linear operators, mathematical representation of dynamic linear systems, concept of state and solution of the state equation, controllability and observability, canonical forms of the state equation, state feedback, and state estimation. Prerequisite: ECE 2210.

ECE 6015. Stochastic Processes in Engineering. 3 Credits.  

ECE 6020. Applied Electromagnetics. 3 Credits.  
Review of Maxwell’s equations; electromagnetics of circuits, plane wave propagation; transmission lines; waveguides; radiating systems; receiving antennas and pattern reciprocity, array antennas; electromagnetic properties of materials: conductors, crystals, devices; optical transmission. Prerequisite: ECE 4320.

ECE 6025. Signals and Transforms in Engineering. 3 Credits.  
Representation of discrete and analog signals as sums of canonical elementary functions; normal equations and the LMS approximation theory, singular value decomposition for discrete and continuous signals; application of classical transform theory to the study of linear systems. Prerequisite: ECE 2210; APSC 2114.

ECE 6030. Device Electronics. 3 Credits.  
Semiconductor device concepts; doping, drift diffusion, recombination. Analysis of Schottky and Ohmic contacts, pn junctions, MOS systems. Modeling and analysis of semiconductor devices such as MOSFET and bipolar transistors. Hot electron and short and narrow channel effects. Prerequisite: ECE 6221.

ECE 6035. Introduction to Computer Networks. 3 Credits.  

ECE 6045. Special Topics. 1-3 Credits.  
Topics to be announced in the Schedule of Classes. (Fall and spring).

ECE 6050. Research. 1-12 Credits.  
Applied research and experimentation projects, as arranged. May be repeated for credit.

ECE 6060. Electric Power Generation. 3 Credits.  
Overview of primary traditional and alternative energy sources and storage. Analysis of machinery employed in energy conversion processes. Effect of independent power producers on long-term and short-term stability of large grids. Prerequisite: ECE 4620 or permission of course director.

ECE 6065. Colloquium. 0 Credits.  
Lectures by outstanding authorities in electrical and computer engineering. Topics to be announced each semester. (Fall and spring).

ECE 6105. Introduction to High-Performance Computing. 3 Credits.  
Taxonomy and classifications of computers and parallel computers. Parallel thinking and parallel algorithms. Domain decomposition and load balancing. Programming parallel computers using the message passing, global address space, and partitioned global address space paradigms. Prerequisite: graduate standing in science or engineering or consent of instructor.

ECE 6120. High-Performance Processors. 3 Credits.  
Processor microarchitecture and instruction-level parallelism. Superpipelines and superscalar processors. Multiple-instruction fetching, aligning, merging, and issuing. Hardware and software solutions to structural and data and control hazards. Branch prediction and static and dynamic speculation. Register renaming, Tomasulo’s algorithm. VLIWs. Prerequisite: ECE 6005.
**ECE 6125. Parallel Computer Architecture. 3 Credits.**
Architectural classifications and taxonomies of parallel computers; enabling technologies, including advanced processor concepts, interconnection networks, high-speed memory architectures and protocols; parallel performance and scalability; and introduction to parallel algorithms and parallel programming. Prerequisite: ECE 6005 or ECE 6105.

**ECE 6130. Grid and Cloud Computing. 3 Credits.**
Introduction to grid, cloud, and distributed computing. Large-scale computing and storage systems. Network protocols, quality-of-service and security issues. Hardware infrastructure and middleware. Distributed algorithms, programming tools, operating and file systems. Prerequisite: ECE 6105.

**ECE 6140. Embedded Systems. 3 Credits.**
Architectural advances and instruction sets for embedded microprocessors. Real-time operating systems and real-time scheduling, use of pre-designed software and hardware cores. Sensors, actuators, and data acquisition. System-on-chip (SoC). Design case studies. Prerequisite: ECE 6005.

**ECE 6213. Design of VLSI Circuits. 3 Credits.**
Top-down ASIC-FPGA design methodology. Modeling of VLSI circuits using HDL. Behavioral, structural, and RTL modeling techniques; validation and verification techniques. Introduction to logic synthesis. Intellectual property usage. Students design and simulate a project using state-of-the-art commercial VLSI CAD tools. Prerequisite: ECE 4140.

**ECE 6214. High-Level VLSI Design Methodology. 3 Credits.**
High-level ASIC-FPGA design methodology. RTL modeling of VLSI circuits, using HDL for synthesis. Detailed discussion of logic synthesis. Architectural tradeoff for large VLSI circuits. Advanced optimization techniques. VLSI design flow, using the state-of-the-art, front-end design entry and simulation tools and back-end logic synthesis. Prerequisite: ECE 6213.

**ECE 6215. Introduction to MEMS. 3 Credits.**
MicroElectroMechanical Systems. Micra/nano fabrication techniques, bulk micromachining, surface micromachining. Examples of mechanical sensors and actuators, examples of microsystems, interface circuits and MEMS applications. Use of the CAD tools to design MEMS devices. May be taken by undergraduates. Prerequisite: ECE 4140.

**ECE 6216. RF/VLSI Circuit Design. 3 Credits.**
Introduction to radio frequency systems: RF design, noise, amplifiers, specifications, matching concepts, mixers, oscillators, system-level design. Prerequisite: ECE 4140.

**ECE 6218. Advanced Analog VLSI Circuit Design. 3 Credits.**
MOS technology: building blocks, devices, capacitors, limitations. Operational amplifiers and other analog systems. Layout examples and design principles. Mixed-signal A/D and D/A. Students use the CAD VLSI laboratory to design and simulate circuits. Prerequisite: ECE 4140.

**ECE 6221. Introduction to Physical Electronics. 3 Credits.**

**ECE 6240. VLSI Design and Simulation. 3 Credits.**
Study of VLSI circuit design including PMOS and NMOS transistor analysis, switch and gate logic design, understanding of semiconductor fabrication processes and design rules, CAD system, speed and power considerations, scaling of transistors to the nano-scale, and designing with highly variable process parameters. Each student will design a VLSI chip, simulate the design and submit a GDS II file for Chip fabrication. (Same as ECE 4140) (Fall).

**ECE 6250. ASIC Design and Testing of VLSI Circuits. 3 Credits.**
ASIC and mixed-signal design methodology, use of ASIC design CAD tools. Logic synthesis, styles of synthesis, power/area/speed constraints. MIPS CPU HDL implementation/verification/testing. VLSI testing, fault models, design for testability techniques, scan path, built-in self-test. Testing of chips designed and fabricated in ECE 4140 or equivalent chips. (Same as ECE 4150) (Spring).

**ECE 6260. Introduction to Nanoelectronics. 3 Credits.**
Nanoscience and technology and nanoelectronics. Basic nanofabrication steps; techniques to build devices such as carbon nanotubes, graphene device, and other 2D nanoelectronic devices. Tools for performing design and characterizations of nanodevices, including scanning electron microscopy (SEM), atomic force microscopy (AFM), and transmission electron microscope (TEM). (Same as ECE 4160) (Fall).

**ECE 6500. Information Theory. 3 Credits.**
The concepts of source and channel. Measure of information, entropy, mutual information. The noiseless coding theorem. The noisy coding theorem. Channel capacity: symmetric and nonsymmetric channels, Gaussian and binary symmetric channels. Rate-distortion theory. Basics of multiple-user information theory. Prerequisite: ECE 6015.

**ECE 6505. Error Control Coding. 3 Credits.**
Algebraic coding theory: finite fields, linear block codes, cyclic and Reed-Solomon codes. Error detection using CRC codes. Convolutional codes and trellis-coded modulations: structure, properties, performance bounds. Capacity achieving codes; soft-input-soft-output decoding; computationally efficient decoding algorithms. Prerequisite: ECE 6015.
ECE 6510. Communication Theory I. 3 Credits.
Principles of digital communications. Channels, digital modulation; optimum receivers and algorithms in the AWGN; coherent, non-coherent, and fading channels. Correlation detectors, matched filters; diversity. Bounds on performance of communications, comparison of communications systems and implementation issues. Prerequisite: ECE 6015.

ECE 6520. Mobile & Wireless Comm Systems. 3 Credits.

ECE 6525. Satellite Communication Systems. 3 Credits.
Low earth orbit and geostationary satellite systems. Transmission systems. RF link budgets. Modulation and multiplexing. Multiple access techniques: FDMA, TDMA, CDMA. Satellite transponders, antennas, and earth stations. Prerequisite: ECE 6510.

ECE 6530. Electronic Warfare. 3 Credits.
Electronic attack and protection of information. Countermeasures and counter-countermeasures. Electronic attacks on ranging and tracking radar systems, jamming and jamming defense. Electronic attack on communications systems. Defensive techniques, signal design, spread spectrum. Attack and defense of optical and high-energy systems. Prerequisite: ECE 6510.

ECE 6550. Advanced Network Architectures. 3 Credits.

ECE 6555. Networks Protocols. 3 Credits.
Layering, OSI, and Internet architectures. Link-layer protocols: PPP, HDLC, SONET. Cell-switching, ATM, and adaptation protocols. MAC layer protocols: Ethernet, 802.11. IP addressing, routing protocols: RIP, OSPF. Multi-domain routing: CIDR, BGP. End-to-end protocols: UDP, TCP. TCP congestion control. Application layer protocols: DNS, HTTP, SMTP, FTP. Prerequisite: ECE 3415 or ECE 6035.

ECE 6560. Network Performance Analysis. 3 Credits.
Telecommunications traffic models: arrival and service time distributions, Poisson and Erlang formulas. Topological design algorithms. Delay and blocking models and probabilities for packet switched networks. Routing, relaying, and flow control algorithms: delay and cost minimization, throughput optimization. Prerequisite: ECE 6015 and any of ECE 6035, ECE 6545, or ECE 6555.

ECE 6565. Telecommunications Security. 3 Credits.
Speech and data scrambling. Linear and nonlinear transformations. Cryptographic techniques. Block and stream ciphers. The Data Encryption Standard (DES). Key management, digital signatures, message authentication, hash functions. Public key algorithms. Prerequisite: graduate standing in science or engineering or consent of instructor.

ECE 6570. Telecommunications Security Protocols. 3 Credits.
The OSI security architecture: services and mechanisms, risk analysis. Internet protocol mechanisms. IPv4 and IPv6 security, security associations, authentication, MD5. Encapsulating security payload. E-mail security: PGP, S/MIME, PEM, MSP. Secure voice communications algorithms. Security in Internet commerce: SSL, SET. Prerequisite: ECE 6565, ECE 6555.

ECE 6575. Optical Communication Networks. 3 Credits.

ECE 6580. Wireless Networks. 3 Credits.

ECE 6610. Electrical Energy Conversion. 3 Credits.
Three-phase and single-phase AC rotating machines and transformers, DC machines, rotating machines as circuit elements, power semiconductor converters. Renewable generation, utility grid integration, smart grid applications. May be taken for graduate credit by students in fields other than electrical engineering. Prerequisites: ECE 2210 and ECE 3315. (Same as ECE 4610) (Spring).

ECE 6620. Electrical Power Systems. 3 Credits.
AC power grids, transmission line parameters, load flow, economic dispatch voltage, frequency, and power flow control. Voltage, current, and power limitations. Fault analysis and stability considerations. Effect of independent power producers and variable energy sources and energy storage. (Same as ECE 4620) (Fall).

ECE 6662. Power Electronics. 3 Credits.
Power semiconductors and applications to power supply, frequency control, uninterruptibility, and the design of HVDC power transmission. Multiphase power electronic circuits for AC and DC machines and industrial processes. Role of power electronics for renewable energy sources interconnected to distribution grids. Prerequisite: ECE 4625.
ECE 6666. Power System Transmission, Control, and Security. 3 Credits.
Analysis of AC networks, load flow, economic dispatch, voltage and frequency control. N-1 contingency and its role in assessing and maintaining system integrity. Analysis of loss of critical generating units and transmission capabilities under severe threats. Rapid restoration techniques based on historical data and heuristic approaches. Prerequisite: ECE 4620 or permission of course director.

ECE 6667. Nuclear Power Generation. 3 Credits.
Review of Nuclear Reactor Engineering, traditional and developing reactor design, issues regarding the safe operation of nuclear plant, control and regulatory aspects of nuclear power generation. Prerequisites: ECE 4620 or permission of course director. (Fall, even years).

ECE 6668. Power Distribution Grids. 3 Credits.
Equipment for power distribution for industrial, commercial, and residential applications. Switching and safety at the distribution voltage level. Bulk insulation level and insulation coordination principles. Smart grid innovations. Remote metering. Prerequisites: ECE 4620 or permission of course director. (Fall, odd years).

ECE 6669. Developing Trends in Electrical Power Networks. 3 Credits.
Planning and operating efficient electric utility power systems. Economics, finance, and regulation; industrial power economics; load demand and management. Reliability of the generation system, capacity and transmission planning. Prerequisites: ECE 4620 or permission of course director. (Spring, odd years).

ECE 6670. Power System Protection. 3 Credits.
Main philosophy for protection of power systems. Protection systems and approaches. Reliability and Security of Protection Systems. Protection of Generators, Transformers, Motors and Transmission Lines. Requirements for Distributed Source Generation (DSG’s). Requirements for system protection, to prevent grid blackouts and to enhance power system security. Prerequisites: ECE 4620 or permission of course director. (Spring, odd years).

ECE 6671. Antennas. 3 Credits.
Polarization. Radiation from current distributions, equivalent integral equations and the moment method. Prerequisite: ECE 6020.

ECE 6672. Electromagnetic Radiation and Scattering. 3 Credits.
Alternative representations of solutions to Maxwell equations, Fourier transforms and spherical mode representations, field equivalence principles, dyadic Green’s functions, radiation and scattering by simple shapes, geometrical theory of diffraction, integral equations and the moment method. Prerequisite: ECE 6020, ECE 6025.

ECE 6691. Power Systems Reliability. 3 Credits.
Overview of probability theory and basic power market reliability modeling and evaluation. Generation supply reliability techniques. Reliability of transmission system and delivery of supply. Loss of load probability evaluation. Forced and maintenance outages. Load forecasting and probability of interconnected systems. Risk evaluation and operating reserves. Prerequisites: ECE 4620 or permission of course director. (Spring, even years).

ECE 6699. Energy and Sustainability. 3 Credits.
Energy sources, consumption, and the societal and environmental impacts. Energy generation and harvesting technology. Thermodynamics and efficiency limits. Nanotechnology for sustainability. Emission and pollution. Growth models; learning curves. Life-cycle analysis. Energy in an international perspective: origins, crises, and solutions. Recommended background: Basic understanding of energy and thermodynamics, such as ECE 4620, MAE 2131, or with permission from the course director. (Fall, even years).

ECE 6705. Introduction to Microwave Engineering I. 3 Credits.
Transmission lines, scattering parameters, microwave networks, resonators. Modes in uniform waveguides, general characteristics of waveguide junctions. Transfer representations, filters, couplers, symmetrical waveguide junctions. Prerequisite: ECE 6020.

ECE 6710. Introduction to Microwave Engineering II. 3 Credits.
Active microwave components, amplifiers, oscillators, and mixers. Design of microwave amplifiers and oscillators, microwave transmitters and receivers. Introduction to microwave systems: radar, wireless communication systems, and radiometer systems. Prerequisite: ECE 6705.

ECE 6715. Antennas. 3 Credits.
Antenna circuits, radiation pattern, reciprocity, gain, receiving cross-section, scattering by antennas, mutual coupling, arrays. Polarization. Radiation from current distributions, equivalent aperture currents, dipoles, patch antennas, large phased arrays. Prerequisite: ECE 6020.

ECE 6720. Remote Sensing. 3 Credits.
Active and passive remote-sensing systems: scatterometers, real-aperture imaging, and synthetic-aperture radars. Sensing of surface, subsurface, and atmospheric parameters at microwave, infrared, and optical frequencies. Analysis of radiometric techniques using radiative transport theory, inverse scattering methods, profile inversion. Prerequisite: ECE 6020.

ECE 6725. Electromagnetic Radiation and Scattering. 3 Credits.
Overview of probability theory and basic power market reliability modeling and evaluation. Generation supply reliability techniques. Reliability of transmission system and delivery of supply. Loss of load probability evaluation. Forced and maintenance outages. Load forecasting and probability of interconnected systems. Risk evaluation and operating reserves. Prerequisites: ECE 4620 or permission of course director. (Spring, even years).
ECE 6730. Waves in Random Media. 3 Credits.
Propagation and scattering of electromagnetic, optical, and acoustic waves in random media, scattering from rough surfaces and randomly distributed particles, turbulence. Applications to propagation through rain and fog. Laser beam scintillations, remote sensing, and communications channel modeling. Monte Carlo simulation. Prerequisite: ECE 6015, ECE 6725.

ECE 6735. Numerical Electromagnetics. 3 Credits.

ECE 6745. Analysis of Nonlinear and Multivalued Devices. 3 Credits.

ECE 6750. Introduction to Radar Systems. 3 Credits.

ECE 6760. Propagation Modeling in Wireless Communications. 3 Credits.
Wireless communication channel modeling, propagation mechanisms, terrestrial fixed links, satellite fixed links, macrocells, fading models, micro-cells, picocells, diversity, equalizers. Prerequisite: ECE 6020 or permission of instructor.

ECE 6765. Photonics and Fiber Optics. 3 Credits.
Propagation of light in optical fibers and planar waveguides, absorption and material dispersion effects, polarization, birefringence, spatial and temporal coherence. Components in fiber optic networks: directional couplers, power splitters, tunable filters and diffraction gratings. Prerequisite: ECE 6020.

ECE 6770. Applied Magnetism. 3 Credits.

ECE 6800. Computational Techniques in Electrical Engineering. 3 Credits.

ECE 6810. Speech and Audio Processing by Computer. 3 Credits.

ECE 6815. Microarchitect/Multimedia Proc. 3 Credits.

ECE 6820. Real Time DSP. 3 Credits.
Digital signals, binary number representation, fixed-point and floating-point DSP architectures. Q-format for data representation, bit allocation and arithmetic. Portability of arithmetic expressions: floating point vs. fixed point. Applications to signal parameter estimation, signal generation, filtering, signal correlation, spectral estimation (FFT). Prerequisite: ECE 6005.

ECE 6825. Computer Control Systems. 3 Credits.
Analysis of automatic control systems in which the control procedure uses on-line digital computation. Topics include single- and multirate sampling, z-transforms, responses of discrete systems, stability criteria, and discrete control design. Prerequisite or concurrent registration: ECE 6010.

ECE 6830. System Optimization. 3 Credits.

ECE 6835. Nonlinear Systems. 3 Credits.

ECE 6840. Digital Image Processing. 3 Credits.
ECE 6842. Image Engineering. 3 Credits.
Sensor/camera design and analysis as a system. Detection and noise processes underlying the sensing of optical radiation; the engineering and physics of image formation. Topics covered include radiometry/photometry, optics and image formation, device and camera characterization, and image quality metrics and system design trades. Prerequisites: ECE 6010, ECE 6015. (Fall, even years).

ECE 6845. Image Synthesis. 3 Credits.
Image synthesis techniques, mathematical image models, image reconstruction techniques, color texture synthesis, synthesis of three-dimensional scenes. Prerequisite: ECE 6015.

ECE 6850. Pattern Recognition. 3 Credits.

ECE 6855. Digital Signal Processing Techniques. 3 Credits.
Signal and system representation, sampling and quantization, transform techniques. Recursive and nonrecursive digital filter design, recursive estimation, linear predictive filtering. Fast algorithms for signal processing. Current topics. Prerequisite: ECE 3220 or ECE 6025, and ECE 6015.

ECE 6860. Compression Techniques for Data, Speech, and Video. 3 Credits.

ECE 6865. Signal Detection & Estimation. 3 Credits.

ECE 6875. Wavelets and Their Applications. 3 Credits.

ECE 6880. Adaptive Signal Processing. 3 Credits.

ECE 6885. Computer Vision. 3 Credits.
Image processing; edge detection, segmentation, local features, shape and region description in 2D and 3D. Insights from human vision studies. Representation for vision: object models, synthetic images, matching, gaps, algorithms. Interference, production system, syntactic networks. Planning spatial reasoning for robot vision. Prerequisite: CSCI 6511; ECE 6850.

ECE 6998. Thesis Research. 3 Credits.
ECE 6999. Thesis Research. 3 Credits.

ECE 8150. Advanced Topics in Computer Architecture. 3 Credits.
Examples of topics are interconnection networks, fault tolerance, load balancing, workload characterization, and performance modeling of advanced computer systems. Prerequisite: ECE 6120, ECE 6125.

ECE 8999. Dissertation Research. 0-12 Credits.
Limited to Doctor of Philosophy candidates. May be repeated for credit.