

ELECTRICAL AND COMPUTER ENGINEERING (ECE)

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 and Computer Engineering I. 1 Credit.

Basic and emerging concepts in electrical and computer biomedical engineering; professional literature and resources; technical writing, speaking, and presentation skills. Practical experiments and projects. (Fall, Every Year).

ECE 1020. Introduction to Electrical and Computer Engineering II. 1 Credit.

Continuation of ECE 1010. Basic and emerging concepts in electrical and computer engineering; professional literature and resources; technical writing, speaking, and presentation skills. Practical experiments and projects. (Spring, Every Year).

ECE 1120. C Programming for Electrical and Computer Engineering. 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. Credit cannot be earned for both this course and CSCI 1121. (Spring, Every Year).

ECE 1125. Data Structures and Algorithms for ECE. 3 Credits.

Fundamentals of algorithms and data structures for electrical and computer engineering; 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. Prerequisite: ECE 1120. (Fall, Every Year).

ECE 2110. Circuit Theory. 4 Credits.

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. Corequisites: APSC 2113, PHYS 1022, and PHYS 2016. (Fall and spring, Every Year).

ECE 2115. Engineering Electronics. 4 Credits.

Solid state devices used in electronic engineering; physics of their operation; application to electronic circuits. Application of these elements in power supplies and in linear amplifiers. Design concepts through use of SPICE and graphical techniques. Prerequisite: ECE 2110. (Spring, Every Year).

ECE 2120. Engineering Seminar. 1 Credit.

A detailed view of the electrical and computer engineering professions. Departmental and other speakers discuss facets of ECE, engineering education, and other department, college, or university topics of interest. (Fall, Every Year).

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

Boolean algebra; combinational and sequential circuits; minimization techniques; design-and-build logic subsystems, such as decoders, multiplexers, adders, and multipliers; use of CAD tools. Prerequisite: ECE 2110. (Fall, Every Year).

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

Circuit analysis using Laplace transforms; transfer functions; poles and zeroes; 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. (Spring, Every Year).

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. (Fall, Every Year).

ECE 3130. Digital Electronics and Design. 4 Credits.

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. (Fall, Every Year).

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. Introduction to Digital Signal Processing. 3 Credits.

Signal representation, sampling, discrete-time signals, z-transforms and spectra, difference equations; Fourier analysis; discrete Fourier transform, IIR and FIR filter design. Prerequisite: ECE 2210. (Fall, Every Year).

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. Prerequisites: APSC 2113, and PHYS 1022 or PHYS 1026. (Spring, Every Year).

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; Magnetostatics, Biot-Savart Law, Maxwell's equations, vector magnetic potential, inductance, magnetic energy, boundary conditions. Prerequisites: APSC 2113; and PHYS 1022 or PHYS 1026. (Fall, Every Year).

ECE 3410. Communications Engineering. 3 Credits.

Fourier series and Fourier transform in relation to signal analysis; convolution and linear filtering; signal bandwidth and sampling theorem; analog modulation; random variables and stochastic processes; power spectrum; digital modulation: BPSK, QPSK, MSK; pulse code modulation, DPCM, and delta modulation. Prerequisites: APSC 3115 and ECE 2210. (Spring, Every Year).

ECE 3420. Communications Laboratory. 1 Credit.

Experiments supporting communications systems. Fourier analysis and Fourier transform. Sampling theorem, filtering, and aliasing. Amplitude modulation (AM), frequency modulation (FM), quantization, and pulse code modulation (PCM). Delta modulation. Binary phase shift keying (BPSK). Quadrature phase shift keying (PSK). Prerequisite or corequisite: ECE 3410.

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. Prerequisite: ECE 2140. (Fall, Every Year).

ECE 3520. Microprocessors: Software, Hardware, and Interfacing. 3 Credits.

Microprocessor architecture, address decoding, hardware interrupt, parallel and serial interfacing with various circuits, timer/counters, direct memory access, microprocessor-based system. Prerequisites: ECE 1120 and ECE 2140. (Fall, Every Year).

ECE 3525. Introduction to Embedded Systems. 3 Credits.

Microcontrollers and their application in embedded systems 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. Prerequisites: ECE 1120 and ECE 3520. (Spring, Every Year).

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

Shared and distributed memory computer systems. Parallel computation. Interprocess communication and synchronization. Terminal, file transfer, and message handling protocols. Algorithms for deadlock detection, concurrency control, and synchronization in distributed systems. Network security and privacy. Resource control and management. Prerequisite: ECE 3515.

ECE 3915W. Electrical and Computer Engineering Capstone Project Lab I. 1 Credit.

Program majors take ECE 3915, ECE 4920, and ECE 4925 in sequence beginning in the second semester of their junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project. Includes a significant engagement in writing as a form of critical inquiry and scholarly expression to satisfy the WID requirement. (Spring, Every Year).

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. (Fall).

ECE 4145. Micro- and Nanofabrication Techniques. 3 Credits.

Introduction to the basic fabrication principles at the micro and nano scale; students practice and fabricate simple devices. Prerequisite: ECE 2110. (Same as ECE 6245) (Fall, Every Year).

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. 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. Prerequisite: ECE 4140. (Same as ECE 6250) (Spring, Every Year).

ECE 4155. Modern Measurements and Sensors. 3 Credits.

Sensor technologies for measurement of mechanical, optical, magnetic, electromagnetic, thermal, and acoustic signals; interface electronic components, calibration, noise, and nonlinearity in addition to more modern sensors and sensor networks, May be taken for graduate credit with the expectation that additional work will be required. Prerequisite: ECE 3125. (Spring, Every Year).

ECE 4160. Introduction to Nanoelectronics. 3 Credits.

Nanoscience and technology and nanoelectronics. Basic nanofabrication steps, and 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). Prerequisite: ECE 2115. (Same as ECE 6260) (Fall, Every Year).

ECE 4320. Fields and Waves II. 3 Credits.

Magneto-stationary 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. Prerequisites: APSC 2114 and ECE 3315. (Spring, Every Year).

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 4415. Introduction to Computer Networks. 3 Credits.

Layered protocol architectures; digital transmission and fundamental limits; error detection and ARQ protocols; data link layer and control; multiple access protocols; circuit and packet switching; multiplexing; routing; flow and congestion control and queue management; LAN standards; TCP/IP; Next-generation Internet. Prerequisite: APSC 3115. (Spring).

ECE 4425. 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. ECE 4415 may be taken as a corequisite. Prerequisite: ECE 4415. (Spring).

ECE 4435. Fiber Optical Communications. 3 Credits.

Lightwave fundamentals. Integrated optics. Optical fiber waveguides. Light sources and detectors. Distribution networks and fiber components. Modulation. Noise and detection. System design. Prerequisite: APSC 2114; ECE 3310 or ECE 4320.

ECE 4535. Computer Architecture and Design. 3 Credits.

Advanced topics in computer architecture and design; instruction-level parallelism, thread-level parallelism, memory, multithreading, and storage systems. Prerequisite: ECE 3515. (Same as ECE 6005) (Fall, Every Year).

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. Prerequisites: ECE 2210, ECE 3315. (Same as ECE 6610) (Spring, Every Year).

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 inversion 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, Every Year).

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.

Modeling and analysis of robot designs. Kinematics of mechanical linkages, structures, actuators, transmissions, and sensors. Design of robot control systems, computer programming, and vision systems. Use of artificial intelligence. Current industrial applications and limitations of robotic systems. Same as MAE 3197. Prerequisite: computer programming, APSC 2058, ECE 4710.

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 and Computer Engineering Capstone Project Lab II. 3 Credits.

Program majors take ECE 3915, ECE 4920, and ECE 4925 in sequence beginning in the second semester of their junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project. Includes a significant engagement in writing as a form of critical inquiry and scholarly expression to satisfy the WID requirement. (Fall, Every Year).

ECE 4925W. Electrical and Computer Engineering Capstone Project Lab III. 3 Credits.

Program majors take ECE 3915, ECE 4920, and ECE 4925 in sequence beginning in the second semester of their junior year. After an introduction to the formal design process, the student plans, refines, designs, and constructs a one-year project. Includes a significant engagement in writing as a form of critical inquiry and scholarly expression to satisfy the WID requirement. Prerequisite: ECE 4920W. (Spring, Every Year).

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 topics in computer architecture and design; instruction-level parallelism, thread-level parallelism, memory, multithreading, and storage systems. (Fall, Every Year).

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. (Fall, Spring, Every Year).

ECE 6015. Stochastic Processes in Engineering. 3 Credits.

Basic concepts of modeling of random phenomena in electrical and computer systems: probability framework, stationarity, linear filtering. Optimization of discrete and continuous stochastic processes. Elements of performance analysis. (Fall, Spring, and Summer, Every Year).

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. (Fall, Every Year).

ECE 6025. Signals and Transforms in Engineering. 3 Credits.

Signal spaces and approximation. Orthogonal functions. Fourier series and transform. Bandpass signals and modulation. Hilbert transform and analytic signals. Timefrequency analysis. Short-time Fourier transform. Linear systems properties. Laplace transform. Sampling and discrete-time signals. Discrete-time Fourier transform and z-transform. Wavelets. (Fall and Spring, Every Year).

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. (Spring, Every Year).

ECE 6035. Introduction to Computer Networks. 3 Credits.

Layered protocol architectures. Digital transmission, fundamental limits. Error detection and ARQ protocols. Data link layer and control. Multiple access protocols. Circuit and packet switching. Multiplexing. Routing. Flow and congestion control, queue management. LAN standards. TCP/IP. Next-generation Internet. (Fall and spring, Every Year).

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. (Fall, Every Year).

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. Restricted to graduate students in science or engineering or permission of the instructor. (Fall, Every Year).

ECE 6120. Advanced Microarchitectures. 3 Credits.

Review of computer architecture fundamentals of performance and power; pipeline design and hazards; superscalar pipelines, speculation and recovery; fetch logic and instruction caches; branch prediction; decoder logic for CISC and RISC; scheduling and instruction issue; ALUs and register files; memory optimizations (scheduling, value prediction); commit logic. Prerequisite: ECE 6005. (Spring, Every Year).

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. Prerequisites: ECE 6005 or ECE 6105. (Spring, Every Year).

ECE 6130. Big Data and Cloud Computing. 3 Credits.

Research topics related to big data and cloud computing, including data centers, virtualization, hardware and software architecture; system-level issues on performance, energy efficiency, reliability, scalability, and security. Prerequisites: ECE 6005 or ECE 6105. (Spring, Every Year).

ECE 6132. Secure Cloud Computing. 3 Credits.

Security concerns and best practices for cloud computing and cloud services; cloud computing architectures, risk issues and legal topics; data security; internal and external clouds; information security frameworks and operations guidelines. Restricted to students in the MEng in cybersecurity policy and compliance program. (Fall, spring, and summer, Every Year).

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. (Fall, Every Year).

ECE 6150. Design of Interconnection Networks for Parallel Computer Architectures. 3 Credits.

The course is intended to provide students with an in-depth study and fundamental design principles of interconnection networks for parallel computing architectures including Network-on-Chips for multicores & Chip Multiprocessors (CMPs), interconnection networks for multiprocessors, multi-computers, and datacenters. Topics include interconnect topologies; routing protocols & algorithms; switching techniques; flow control protocols; router design; modeling and simulation tools; interconnect reliability, scalability, and security; and emerging technologies for interconnects (Optical, Wireless, Radio Frequency). The material covered in this course bridges the gap between courses such as VLSI, parallel computer architecture, high-performance computing, and computer networks. Restricted to SEAS Graduate Students. Prerequisites: ECE 6005 or equivalent course. Recommended background: Students in this course should have taken a prior course in computer organization or computer architecture. (Spring, Every Year).

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; logic synthesis techniques; design verification plan and techniques. Students design and verify a final project using state of the art commercial VLSI CAD tools for ASIC and FPGA (Altera). Prerequisite: ECE 6240. (Fall, Every Year).

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. (Spring, Every Year).

ECE 6215. Introduction to MEMS. 3 Credits.

Introduction to microelectromechanical and nanoelectromechanical systems (MEMS/NEMS). Basic principles of simulating, designing, and fabricating MEMS/NEMS. Prerequisite: ECE 6240. (Spring, Every Year).

ECE 6216. RF/VLSI Circuit Design. 3 Credits.

Introduction to radio frequency systems. RF design, specifications, S-parameters, gain, noise, stability, matching concepts, small signal amplifiers, low noise amplifiers, power amplifiers, system-level design. Students use CAD tools such as ADS and other industrial tools to design class project. Prerequisite: ECE 6240. (Spring, Odd Years).

ECE 6218. Advanced Analog VLSI Circuit Design. 3 Credits.

MOS technology: building blocks, devices, capacitors, limitations; perational 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 6240. (Spring, even years).

ECE 6221. Introduction to Physical Electronics. 3 Credits.

Theoretical principles underlying the operation of electronic devices. Postulates of quantum mechanics: wave-particle duality, uncertainty relations, electronic band structure. Free-carrier statistics; electron-photon interaction. Physical principles of semiconductor and optoelectronic devices. (Fall, Every Year).

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, Every Year).

ECE 6245. Micro and Nano Fabrication Technology. 3 Credits.

Introduction to the basic fabrication principles at the micro and nano scale; students practice and fabricate simple devices. Restricted to graduate students. Prerequisite: ECE 2150. (Fall, Every Year).

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. Chips designed and fabricated in ECE 4140 or ECE 6240 or equivalent course are tested. Prerequisites: ECE 4140 or ECE 6240. (Spring, Every Year).

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, Every Year).

ECE 6500. Information Theory. 3 Credits.

Introduction to the mathematical representation of information, including the concepts of entropy, mutual information and information transfer over noisy media; mathematical representation of information sources; entropy and mutual information; noiseless and noisy coding theorems; data compression; communication channels and their capacity to convey information; and rate distortion theory. Prerequisite: ECE 6015. (Spring, odd years).

ECE 6505. Error Control Coding. 3 Credits.

Introduction to the principles governing the mathematical theory of error detecting and correcting errors occurring in the transfer of information over digital communication channels. Prerequisite: ECE 6015. (Spring, Every Year).

ECE 6510. Communication Theory. 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. (Spring, Every Year).

ECE 6520. Mobile and Wireless Communication Systems. 3 Credits.

Characterization of mobile and wireless channels. Indoor and outdoor path loss models. Multipath propagation. Fading. Fading countermeasures (coding and equalization). Power control. Cellular design and frequency reuse. Modulation and coding techniques. Spread spectrum and orthogonal frequency-division multiplexing (OFDM). Space-code division multiple access (SCDMA), multiple-input and multiple-output (MIMO). Prerequisite: ECE 6510. (Fall, Odd Years).

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, including FDMA, TDMA, and CDMA; satellite transponders, antennas, and earth stations. Prerequisite: ECE 6510. (Fall, Every Year).

ECE 6530. Electronic Warfare. 3 Credits.

Electronic attack and protection of information; countermeasures and counter-countermeasures; attacks on ranging and tracking radar systems; jamming and jamming defense; attacks on communications systems; defensive techniques, signal design, spread spectrum; attack and defense of optical and high-energy systems. Offered as arranged. Prerequisite: ECE 6510. (Fall and spring, Every Year).

ECE 6550. Network Architectures and Protocols. 3 Credits.

Network topologies and control structures; switching and routing of information streams; Internet transmission protocols; data representations and codes; application protocols; mail and file transfer protocols; and network management systems. Prerequisite: ECE 6035. (Spring, Every Year).

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, ECE 6035. (Fall, Every Year).

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 (ESP); e-mail security: PGP, S/MIME, PEM, MSP; secure voice communications algorithms; security in Internet commerce: SSL, SET. Offered as arranged. Prerequisites: ECE 6035 and ECE 6565. (Fall and spring, Every Year).

ECE 6575. Optical Communication Networks. 3 Credits.

Wave propagation through fiber, dispersion, and polarization; multiplexing techniques, WDM; optical networking components; optical transmission systems design; all-optical networking, broadcast star, and wavelength routing networks. Performance analysis, survivability, control, and management; optical access networks. (Fall, Every Year).

ECE 6580. Wireless Networks. 3 Credits.

Traffic models for wireless networks; wireless network architectures; physical, MAC, and link layer protocols for wireless networks; TDMA, CDMA, and OFDM-based cellular networks; third- and fourth-generation cellular networks; wireless local area networks; IEEE 802.11, 802.15 and 802/16 developments; Wi-Fi, Bluetooth, and WiMAX; cordless telephone technology. Prerequisite: ECE 6035. (Spring, Every Year).

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. (Spring, Every Year).

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, Every Year).

ECE 6662. Power Electronics. 3 Credits.

The application of electronics to energy conversion. Principles of operation, analysis, and control of circuits including solid-state electronic switches. Methods of solving power electronic circuits and finding the steady-state values of important quantities. Deriving the linear model of the studied power electronic circuits and designing controllers for these devices. A general knowledge of electric circuits and linear control theory is required. (Spring, Every Year).

ECE 6666. Power System Transmission, Control, and Security. 3 Credits.

Analysis of AC networks, load flow, transient stability, economic dispatch, reactive compensation, FACTS, effects of alternative generation, voltage and frequency control, N-1 contingency, restoration techniques. Offered as arranged. Prerequisite: ECE 6620. (Fall and spring, Every Year).

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, and control and regulatory aspects of nuclear power generation. Prerequisites: ECE 6620 or permission of the instructor. (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. Prerequisite: ECE 6620. (Fall, odd years).

ECE 6669. Smart Power Grids. 3 Credits.

Probability theory; basic power market reliability modeling and evaluation; generation supply reliability techniques, modeling and evaluation; reliability of transmission system and delivery of supply; loss of load probability evaluation; forced and maintenance outages and impact on system reliability; load forecasting and probability of interconnected systems; risk evaluation in power system operation; operating reserve techniques and indices; distribution system reliability including substations; composite system reliability modeling; reliability worth and value. (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); and requirements for system protection to prevent grid blackouts and enhance power system security. Prerequisite: ECE 6620 or permission of instructor. (Spring, Even Years).

ECE 6690. Power Systems Economics. 3 Credits.

Overview of electrical power market economics and market participants; production pricing and market clearing pricing; market ancillary service pricing. Location marginal pricing and zonal pricing schemes; new electrical generation entrant impact; investing in generation and in transmission; independent power producers and independent transmission owners. Offered as arranged. (Summer, Every Year).

ECE 6691. Power Systems Reliability. 3 Credits.

Probability theory; basic power market reliability modeling and evaluation; generation supply reliability techniques, modeling and evaluation; reliability of transmission system and delivery of supply; loss of load probability evaluation; forced and maintenance outages and impact on system reliability; load forecasting and probability of interconnected systems; risk evaluation in power system operation; operating reserve techniques and indices; distribution system reliability including substations; composite system reliability modeling; reliability worth and value (Spring, even years).

ECE 6699. Energy and Sustainability. 3 Credits.

Energy sources; consumptions; 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. Offered as arranged. Recommended background: A basic understanding of energy and thermodynamics such as material covered in ECE 4620 and MAE 2131. (Summer, Every Year).

ECE 6710. Microwave Engineering. 3 Credits.

Transmission line theory, transmission lines and waveguides, waveguide discontinuities, microwave networks, impedance matching and tuning, microwave resonators, power dividers and directional couplers, and microwave filters and active microwave circuits. Prerequisite: ECE 6020. (Fall, even years).

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. Restricted to graduate students in electrical engineering. Prerequisite: ECE 6020. (Spring, odd years).

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. (Spring, even years).

ECE 6725. Electromagnetic Radiation and Scattering. 3 Credits.

Alternative representations of solutions to Maxwell equations, Fourier transforms and spherical mode representations, field equivalence principle, dyadic Green's functions, radiation and scattering by simple shapes, geometrical theory of diffraction, integral equations and the moment method. Offered as arranged. Prerequisite: ECE 6020. (Summer, Every Year).

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. Offered as arranged. Prerequisite: ECE 6725. (Summer, Every Year).

ECE 6735. Numerical Electromagnetics. 3 Credits.

Systematic discussion of useful numerical methods in computational electromagnetics, including integral equation techniques and differential equation techniques, both in the frequency and time domains. Hands-on experience with numerical techniques, including the method of moments, finite element and finite-difference time-domain methods, and spectral integral methods. Related numerical issues such as accuracy, stability, and dispersion are discussed. Examples are drawn from various electromagnetic applications such as nanowires, waveguides, and antenna radiation. Prerequisite: ECE 6020. (Fall, Odd Years).

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

Numerical techniques for modeling semiconductor and magnetic devices; modeling multivalued behavior of memory materials; optimization of geometry. Offered as arranged. Prerequisite: ECE 6020. (Summer, Every Year).

ECE 6750. Modern Radar Systems. 3 Credits.

The radar range equation; radar cross section of targets, target detection and parameter estimation, detection in clutter; resolution, ambiguities, and signal design; moving-target indicators; pulse-Doppler radar; radar antennas, phased arrays; synthetic aperture and space-based radar Prerequisite: ECE 6020. (Summer, Every Year).

ECE 6760. Propagation Modeling in Wireless Communications. 3 Credits.

Fundamentals of radiowave propagation and antennas with emphasis on recent research innovations in these areas. Prerequisite: ECE 6020. (Spring, odd years).

ECE 6765. Photonics and Fiber Optics. 3 Credits.

Concepts of opto-electronic devices; light-matter-interaction and absorption; device details and applications, including laser, photodetector, and modulators; optical cavity; waveguides and optical fibers; device and link considerations include energy-per-bit, modulation speed, and nano fabrication; plasmonics and nanophotonics. Industry perspective. (Spring, even years).

ECE 6770. Applied Magnetism. 3 Credits.

Classification of magnetic materials; magnetic measurements; soft and hard magnetic materials; applications to microwave, magnetic recording, permanent magnets, magneto-optics, magnetic refrigeration, sensors, magnetostrictive devices; electric power; superconducting devices. Offered as arranged. Prerequisite: ECE 6020. (Fall, Every Year).

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

Introduction to linear algebra and vector spaces as applied to networks and electrical systems; orthogonal bases, projections, and least squares; fast Fourier transforms; eigenvalues and eigenvectors with applications; computations with matrices; constrained optimization in electrical systems; network models and applications; special relativity. (Fall, Every Year).

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

Introduction to computer processing of speech and audio; acoustic sensor technologies and characteristics, direction finding, speech analysis and synthesis, audio formats and compression standards, time-varying autoregressive models, speech recognition, and automatic target recognition. Restricted to graduate students. (Fall, Every Year).

ECE 6815. Multimedia Processing. 3 Credits.

Introduction to multimedia; formats, conversion and combinations; delivery and trends; servers and networks; hardware and architecture; enduser devices; digital libraries, video conferencing and collaboration; and educational and health applications. Offered as arranged. Restricted to graduate students with programming experience in C, C++ or Java. Prerequisite: ECE 6005. (Summer, Every Year).

ECE 6820. Real-Time Digital Signal Processing. 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; development of real-time signal processing software; applications to signal parameter estimation, signal generation, filtering, signal correlation, spectral estimation (FFT). Offered as Arranged Prerequisite: ECE 6005. Recommended background: Basic knowledge of computer architecture and DSP algorithms; knowledge of C programming language, assembly language, and Matlab is desirable. (Spring, Every Year).

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.

Parameter optimization problems, theory of minima and maxima. Optimization problems for dynamic systems, calculus of variations, the maximum principle and the Hamilton-Jacobi equation. Optimization problems with constraints, optimal feedback systems. Numerical solution of optimal problems. Prerequisite: ECE 6010.

ECE 6835. Nonlinear Systems. 3 Credits.

Definition of linear and nonlinear systems; introduction to approximate analysis of nonlinear systems—describing functions, Krylov and Bogoliubov asymptotical method, and Tsytkin locus. Forced oscillations—jump resonance. Stability analysis—Liapunov criterion. Luré problem and Popov method. Prerequisite: ECE 6010.

ECE 6840. Digital Image Processing. 3 Credits.

Properties of images and visual systems; image acquisition, sampling, quantization; one- and two-dimensional image transform techniques; enhancement and restoration; image coding and data compression; segmentation, representation, boundary and shape, texture, matching; image understanding. Prerequisite: ECE 6800. (Spring, odd years).

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.

Introduction to techniques for synthesizing images using mathematical models and other reconstruction techniques; the image formation process and other techniques for synthesizing color textures and three-dimensional scenes. Prerequisite: ECE 6015. (Spring, Every Year).

ECE 6850. Pattern Recognition. 3 Credits.

Random vectors, transformations; hypothesis testing, error probability, sequential methods. Bayes, other linear classifiers; discriminant functions, parameter estimation, learning, and dimensionality reduction; nonparametric methods; clustering; feature selection and ordering; computer applications and projects. Prerequisite: ECE 6015. (Fall, odd years).

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. Prerequisite: ECE 6015. (Fall, Every Year).

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

Lossless and lossy coding theorems, rate distortion bound; data compression algorithms; differential coding; transform coding; voice, audio, image, and video coding techniques; data coding standards. Offered as arranged. Prerequisites: ECE 6015 and ECE 6025. (Fall, Every Year).

ECE 6865. Statistical Signal Estimation. 3 Credits.

Minimum variance unbiased estimation; Cramer–Rao bound, statistical modeling, sufficient statistics, maximum likelihood estimation, efficient estimators, and least squares; Bayesian estimators; Wiener and Kalman filters, complex data and parameters; applications to radar, speech, image, biomedicine, and communications, control. Prerequisite: ECE 6015. (Fall, odd years).

ECE 6875. Wavelets and Their Applications. 3 Credits.

Time-frequency analysis; continuous, discrete, and discrete-time wavelet transform; multirate filter banks; multiband wavelets, two-dimensional wavelets; wavelet packets and matching pursuit; wavelets in noise filtering, compression, modeling of fractals, communications, detection, adaptive systems, neural networks, and fast computation. Prerequisites: ECE 6025 and ECE 6855. (Spring, odd years).

ECE 6880. Adaptive Signal Processing. 3 Credits.

Adaptation criteria; least mean square and recursive least square; convergence of adaptive algorithms and tracking; linear and nonlinear Kalman filters; blind source separation. Iterative (turbo) decoding and equalization; nonlinear/non-Gaussian models: particle filtering; machine learning: back propagation, support vector machines; applications in system identification, adaptive channel equalization, interference cancellation and suppression, and adaptive antenna arrays. Prerequisite: ECE 6865. (Spring, even years).

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: ECE 6850. (Spring, even years).

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.