ELECTRICAL AND COMPUTER ENGINEERING

OVERVIEW

Mission Statement

The mission of the Department of Electrical and Computer Engineering is to inspire our diverse students by providing rigorous and comprehensive programs in electrical engineering and computer engineering in order to provide leadership in a rapidly developing technological society and to advance the state of knowledge in our disciplines by actively pursuing scholarly research.

Computer Engineering Program Educational Objectives

The computer engineering program in GW's Department of Electrical and Computer Engineering prepares graduates who, in the years following graduation, can achieve:

- Employment in industry, government, or other organizations using skills and knowledge learned while an undergraduate student at GW as evidenced by:
  - Employment history and/or career advancements.
  - Professional visibility (e.g., patents, invention disclosures, honors or awards, refereed journal articles, conference papers & other publications, involvement in professional associations).
  - Entrepreneurial activities.

and/or

- Engagement in lifelong learning using skills and knowledge learned while an undergraduate student at GWU as evidenced by:
  - Enrollment in graduate or professional programs.
  - Advanced degree earned.
  - Professional visibility (e.g., patents, invention disclosures, honors or awards, refereed journal articles, conference papers & other publications, involvement in professional associations).

Computer Engineering Program Student Outcomes

The computer engineering program at the GW's Department of Electrical and Computer Engineering aims to produce graduates who have an:

1. Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. Ability to communicate effectively with a range of audiences.
4. Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. Ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Electrical Engineering Program Educational Objectives

The electrical engineering program in GW's Department of Electrical and Computer Engineering prepares graduates who, in the years following graduation, can achieve:

- Employment in industry, government, or other organizations using skills and knowledge learned while an undergraduate student at GWU as evidenced by:
  - Employment history and/or career advancements.
  - Professional visibility (e.g., patents, invention disclosures, honors or awards, refereed journal articles, conference papers & other publications, involvement in professional associations).
  - Entrepreneurial activities.

and/or

- Engagement in lifelong learning using skills and knowledge learned while an undergraduate student at GWU as evidenced by:
- Enrollment in graduate or professional programs.
- Advanced degree earned.
- Professional visibility (e.g., patents, invention disclosures, honors or awards, refereed journal articles, conference papers & other publications, involvement in professional associations).

Electrical Engineering Program Student Outcomes

The electrical engineering program at the GW's Department of Electrical and Computer Engineering aims to produce graduates who have an:

1. Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. Ability to communicate effectively with a range of audiences.
4. Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which

must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

5. Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. Ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

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/)
- Bachelor of Science with a major in electrical engineering, energy option (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/bs-electrical-engineering/energy/)
- Bachelor of Science with a major in electrical engineering, medical preparation option (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/bs-electrical-engineering/medical-preparation/)

Combined programs

- Dual Bachelor of Science with a major in computer engineering and Master of Science in the field of computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/combined-bs-ms-computer-engineering/)
- Dual Bachelor of Science with a major in computer engineering and Master of Science in the field of electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/combined-bs-computer-engineering-ms-electrical-engineering/)
- Dual Bachelor of Science with a major in electrical engineering and Master of Science in the field of computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/combined-bs-electrical-engineering-ms-computer-engineering/)
- Dual Bachelor of Science with a major in electrical engineering and Master of Science in the field of electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/combined-bs-ms-electrical-engineering/)

Minors

- Minor in computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/minor-computer-engineering/)
- Minor in electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/minor-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/) (on-campus)
- Master of Science in the field of electrical engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/electrical-engineering-online/) (online)

Professional programs

See the School of Engineering and Applied Science (https://www.seas.gwu.edu/) for programs leading to the professional degree.

DOCTORAL

Doctoral program

- Doctor of Philosophy in the field of computer engineering (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/phd-computer-engineering/)

CERTIFICATES

Graduate certificate programs

- High-performance computing (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/certificate-high-performance-computing/)
- Machine intelligence: frameworks, systems, and applications (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/certificate-machine-intelligence/)
- 5G and beyond (http://bulletin.gwu.edu/engineering-applied-science/electrical-computer-engineering/5g-and-beyond-certificate/)

FACULTY

Regular Faculty: G. Adam, S. Ahmadi, A. Aslani, W. Cao, P. Dehghanian, M. Doroslovacki, T. El-Ghazawi, K.B. Eom, H. Huang, C.E. Korman, J. Lach, T. Lan, A. Louri, H. Mehrjerdi, S. Subramaniam, G.P. Venkataramani, N. Wu, M. Zaghloul

Research and Visiting Faculty: R. Lang, D. Nagel

Courtesy Appointment: M. Lejeune, M. Loew, P. Wei

Emeritus Faculty: N. Alexandridis, R. Harrington, H. Helgert, N. Kyriakopoulos, T. Lee, M. Pardavi-Horvath, B. Vojcic, W. Wasylkiwskyj

COURSES

Explanation of Course Numbers

- Courses in the 1000s are primarily introductory undergraduate courses
- Those in the 2000s to 4000s are upper-level undergraduate courses that can also be taken for graduate credit with permission and additional work assigned
- 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 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 1099. Variable Topics. 1 Credit.

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. Credit cannot be earned for 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.
Techniques of circuit analysis; circuit theorems; operational amplifiers; RLC circuits; series, parallel and resonant circuits; sinusoidal steady-state analysis; phasers; power calculations; two-port circuits. CAD tools used in circuits projects. Corequisites: APSC 2113; and PHYS 1022 or PHYS 1026. (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. 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. Prerequisites: ECE 2110. Corequisites: ECE 2115. (Spring, 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. Prerequisites: ECE 2110. (Spring, Every year)

ECE 3125. Analog Electronics Design. 4 Credits.
Design, testing, and measurement of analog electronic circuits. Differential, multistage and power amplifiers. Frequency response of amplifiers, high-frequency models of FETs and BJTs. Use of electronic simulation programs, such as Multisim. Prerequisites: ECE 2115. (Spring, 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. Students must have completed a course in logic systems, such as ECE 2140 or equivalent, prior to enrollment. Consult the instructor if uncertain whether this requirement has been met. Prerequisite: ECE 2140. (Fall, Every year)

ECE 3135. Digital Design with Field-Programmable Gate Arrays. 4 Credits.
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. Lecture 3 hours, laboratory 3 hours. Prerequisites: ECE 2140. (Spring, Every year)

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 to digital filters and digital image processing, 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. Prerequisites: APSC 3115 and ECE 2110. (As arranged, Every year)

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. Recommended background: Students in this course should have taken APSC 3115 (Engineering Analysis III) and ECE 2210 (Circuits, Signals, and Systems) or an equivalent course; If unsure, please contact the instructor, and discuss the pre-requisite requirements. (Spring, Every year)

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. Prerequisites: 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. Hands-on laboratory experience using laboratory facilities is an integral part of this course. Prerequisites: ECE 1120 and ECE 2140. (Fall, Every year)

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. Prerequisites: ECE 1120 and ECE 3520. (Spring, Every year)

ECE 3530. Introduction to Parallel and Distributed Computer Systems. 3 Credits.
Parallel Computing versus Distributed Computing Systems. Applications of Parallel Computing and Distributed Computing in Science and Engineering. Computer networks versus interconnection networks of parallel systems; high throughput versus low latency computing systems. Data Centers, Clouds, Grids, Edge, Fog and Cluster Computing. Performance analyses and evaluation of parallel and distributed systems. Shared memory and distributed systems programming with introduction to OpenMP, pthreads, message passing, Hadoob and MapReduce. Synchronization issues and methods. Introduction to the design and analyses of parallel algorithms. Performance Analysis and Program Optimizations. Introduction to GPUs and Heterogeneous systems and programming. Offered as arranged. Prerequisites: ECE 1120 and ECE 1125. (Summer, Every year)

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 gate logic design, CADENCE system, speed and power considerations, highly variable process parameters. Students design VLSI chip and submits GDS file for Chip fabrication. Prerequisites: ECE 3130 and ECE 3135. Credit cannot be earned for this course and ECE 6240. (Fall, Every year)

ECE 4145. Microfabrication and Nanofabrication Technology. 3 Credits.
Introduction to the basic fabrication principles at the micro and nano scale; students practice and fabricate simple devices. Prerequisites: ECE 2110. Credit cannot be earned for this course and ECE 6245. (Fall, Every year)

ECE 4150. ASIC Design and Testing of VLSI Circuits. 3 Credits.
ASIC design techniques, CAD tools. Logic synthesis, styles of synthesis, power/area/speed constraints. VLSI testing, fault models, design for testability, scan path, built-in self-test. Prerequisites: ECE 4140. Credit cannot be earned for this course and ECE 6250. (Spring, Every year)

ECE 4155. Sensors, Networks, and Applications. 3 Credits.
Sensor technologies for mechanical, optical, magnetic, electromagnetic, thermal, and acoustic signals; electronics Interface, calibration, noise, sensor networks. Prerequisites: ECE 3125 or permission of the instructor. Credit cannot be earned for this course and ECE 6255. (Spring, Every year)

ECE 4160. Introduction to Nanoelectronics. 3 Credits.
Nanoscience and technology and nanoelectronics. Basic nanofabrication steps of nanodevices, 2D materials. Use of tools for performing design and characterizations, in the clean room. Prerequisites: ECE 2115. Credit cannot be earned for this course and ECE 6260. (Fall, Every year)

ECE 4320. Fields and Waves II. 3 Credits.
Magnetostatic fields, Lorentz force torques, Biot–Savart law, Ampere's law, magnetic materials, inductance, magnetic 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 4415. Introduction to Computer Networks. 3 Credits.
Layered architectures; digital transmission; error detection and ARQ; multiple access; circuit and packet switching; multiplexing; routing; flow and congestion control; TCP/IP. Prerequisites: APSC 3115. Credit cannot be earned for this course and ECE 6035. (Spring, Every year)

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. Prerequisite: ECE 4415. (Spring, Every year)

ECE 4435. Photonics and Fiber Optics. 3 Credits.
Concepts of opto-electronic devices; light-matter interaction; laser, photodetector, modulator, waveguide, fiber; data modulation, speed; plasmonics and nanophotonics; industry perspective. Prerequisites: APSC 2114; and ECE 3310 or ECE 4320. Recommended background: Prior completion of at least one undergraduate-level course in electromagnetism and semiconductors. Credit cannot be earned for this course and ECE 6765. (Spring, Even years)

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. Prerequisites: ECE 3515. Credit cannot be earned for this course and ECE 6005. (Fall, Every year)

ECE 4545. Operating System Engineering. 3 Credits.
Computer systems course that familiarizes students with core concepts and applied knowledge in computing systems and covers advanced topics in systems design and implementation. Restricted to students in the electrical and computer engineering and computer science programs. Prerequisites: ECE 1120, ECE 1125, and ECE 3515. Credit cannot be earned for this course and ECE 6045. (Fall, Every year)

ECE 4610. Electrical Energy Conversion. 3 Credits.
Three-phase and single-phase AC rotating machines and transformers, DC machines, power semiconductor converters. Renewable generation, utility grid integration, smart grid applications. Prerequisites: ECE 2210, ECE 3315. Credit cannot be earned for this course and ECE 6610. (Spring, Every year)

ECE 4620. Electrical Power Systems. 3 Credits.
AC power grids, transmission line models, voltage, frequency, and power flow. Economic dispatch and fault analysis. Effect of variable energy sources and energy storage. Credit cannot be earned for this course and ECE 6070.

ECE 4662. Power Electronics. 3 Credits.
The application of electronics to energy conversion; analysis, operation and control of power electronic circuits. General knowledge of electric circuits and linear control is required. Credit cannot be earned for this course and ECE 6662.

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. Prerequisites: APSC 2114; and ECE 2210 or MAE 3134. (Fall, Every year)

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 4810. Machine Intelligence. 3 Credits.
Supervised, unsupervised, and reinforcement learning; regression; generative vs. discriminative model; optimization; kernel; SVM; introduction to deep learning and learning theory; clustering. Restricted to students in the electrical and computer engineering and computer science programs. Prerequisites: APSC 2113 and APSC 3115. (Fall, Every year)

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.
ECE 3915, ECE 4920, and ECE 4925W are taken in sequence by departmental majors beginning in the second semester of the junior year. Students are introduced to the formal design process, and plan, refine, design, and construct a one-year project. Prerequisites: ECE 4920W. Includes a significant engagement in writing as a form of critical inquiry and scholarly expression to satisfy the WID requirement. (Spring, Every year)

ECE 4980. Special Topics. 1-3 Credits.
Topic to be announced in the Schedule of Classes.

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

ECE 6005. Computer Architecture and Design. 3 Credits.
Advanced topics in computer architecture and design; instruction-level parallelism, thread-level parallelism, memory, multithreading, and storage systems. Credit cannot be earned for this course and ECE 4535. (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.
Axioms of probability; conditional probability; independent events; sequential experiments. Single and multiple random variables. Discrete-valued and continuous-valued stochastic processes; discrete-time and continuous-time stochastic processes; mean, auto-correlation and autocovariance functions; multiple random processes; stationary stochastic processes and linear time-invariant systems; ergodicity; Markov chains. Examples from engineering applications. (Fall, spring, and summer, Every year)

ECE 6020. Applied Electromagnetics. 3 Credits.
Vector algebra and calculus, Divergence and Stokes theorems, Maxwell's equations, Boundary conditions, Poynting vector theorem, Time harmonic waves, Wave equation, Propagation in lossy media, Skin depth, Plane waves in an arbitrary direction, Polarization, Snell's law, Transmission line equations, Propagation constant, Characteristic impedance, Average power, Waveguides, TEM, TM and TE modes, cutoff frequencies, Vector and scalar potentials, scalar Green's function, Near and far fields from a dipole, radiated power and Antenna fundamentals Recommended background: ECE 4320 or similar course. (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. Time frequency 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 architectures; digital transmission; error detection and ARQ; multiple access; circuit and packet switching; multiplexing; routing; flow and congestion control; TCP/IP. Credit cannot be earned for this course and ECE 4415. (Fall and spring, Every year)

ECE 6045. Special Topics in Electrical Engineering. 3 Credits.
Topics vary by semester. Can be repeated provided topic differs. Consult the Schedule of Classes for more details. (Spring and fall, Every year)

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

ECE 6070. Electrical Power Systems. 3 Credits.
AC power grids, transmission line models, voltage, frequency, and power flow. Economic dispatch and fault analysis. Effect of variable energy sources and energy storage. Credit cannot be earned for this course and ECE 4620.

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 Microarchitecture. 3 Credits.
Review of computer architecture fundamentals 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; commit logic. Prerequisite: ECE 6005. Recommended background: Students should have taken at least one course in computer architecture, such as ECE 6005 or equivalent, prior to enrollment. (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.
This course covers a wide range of research topics related to big data and cloud computing, including data centers, virtualization, hardware and software architecture, as well as 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.
The course provides a comprehensive guide to security concerns and best practices for cloud computing and cloud services. Topics discussed include cloud computing architectures, risk issues and legal topics, data security, internal and external clouds, information security frameworks and operational guidelines. Offered as arranged. Restricted to students in the MEng in cybersecurity policy and compliance program. (Summer, Every year)

ECE 6134. Cloud Computing and Security. 3 Credits.
Comprehensive study on security concerns and best practices for cloud computing. Cloud computing architectures and management, risk issues and data security, privacy, service availability, and robustness. (As arranged, 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.
In-depth study and fundamental design principles of interconnection networks for parallel computing architectures including network-on-chips for multicores and chip multiprocessors (CMPs), interconnection networks for multiprocessors, multi-computers, and datacenters; interconnect topologies, routing protocols and algorithms, switching techniques, flow control protocols, router design, modeling and simulation tools, interconnect reliability, scalability, security, emerging technologies for interconnects (optical, wireless, radio frequency), emerging applications (neuromorphic, quantum, and approximate computing), case studies covering modern commercial examples. Restricted to SEAS graduate students. Prerequisites: ECE 6005 or equivalent. Recommended background: Prior completion of a course in computer organization or computer architecture, which may be ECE 3515 or ECE 6005 or an equivalent. (Spring, Every year)

ECE 6160. Secure Computing Systems. 3 Credits.
Computer security needs; access control, information flow, anonymity; trusted execution environment; side/covert channels; hardware Trojans; reverse engineering; physically unclonable functions; hardware obfuscation; secure architecture case studies. Prerequisites: At least one prior course in computer architecture, such as ECE 6005 or equivalent, if unsure whether the prerequisite has been met, contact the instructor. (As arranged, Every year)

ECE 6210. Machine Intelligence. 3 Credits.
Machine learning theory; classification and linear models; perceptron model; artificial neural networks; training, inference, software, programming; vector matrix multiplications; design vectors of AI system and performance; AI applications. Prerequisites: Undergraduate-level knowledge in electrical and/or computer engineering or computer science. (Fall, Every year)

ECE 6213. Design of VLSI Circuits. 3 Credits.
This class covers 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). (Fall, Every year)

ECE 6214. High-Level VLSI Design Methodology. 3 Credits.
This class covers advanced ASIC-FPGA design methodology including: synthesis methodology for both ASIC and FPGA design flow, DSP design for mobile device and implementation to ASIC and FPGA, low-power SOC design, CPF implementation, area/delay/power optimization and trade-offs, DFT, DFM, Low-Power design for mobile device, and Hardware/Software co-design. Advanced low power design for multi-core CPU architecture, LP top-down design flow with CPF implementation/verification. Students design and verify a final project using ASIC CAD tools and FPGA demo board with built-in LA. Prerequisite: ECE 6213. (Spring, Every year)

ECE 6215. Microsystems Design, Simulation, and Fabrication for Sensor Applications. 3 Credits.
Introduction to microelectromechanical and nanoelectromechanical systems (MEMS/NEMS) for sensor applications. Basic principles of simulating, designing, and fabricating MEMS/NEMS. Prerequisites: Prior completion of at least one course equivalent to ECE 6240. If unsure, contact the instructor to discuss this requirement. (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. In this course students use CAD tools such as ADS and other industrial tools to design class project. Prerequisite: ECE 6240. (Spring, Odd years)

ECE 6217. Neural Networks and Hardware Implementations. 3 Credits.
Theory of neural network and their models. Representation of neural cells; memristor and phase change (PCM) materials; general concept of the multilayer of the neural networks; deep neural networks (DNN); spiking neural networks. Prerequisites: ECE 4140 or ECE 6240; and knowledge of analog circuits design. (Fall, Every year)

ECE 6218. Advanced Analog VLSI Circuit Design. 3 Credits.
CMOS technology, CMOS analog building blocks, current sinks, current sources, current mirrors, voltage references, CMOS amplifier design, feedback circuits, frequency response, compensation. Analysis of circuit variants: cascoding, active replacement elements – non-linear circuits. A/D converter design, examples of CMOS A/Ds. Mixed-signal layout techniques. Students are required to design CMOS Analog Circuit project, and submit final design Layout together with simulation using CAD (CADENCE analog design) simulation tools. Final report is required. 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 gate logic design, CADENCE system, speed and power considerations, highly variable process parameters. Students design VLSI chip and submits GDS file for Chip fabrication. Credit cannot be earned for this course and ECE 4140. (Fall, Every year)

ECE 6245. Microfabrication and Nanofabrication 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. Prerequisites: ECE 2150. Credit cannot be earned for this course and ECE 4145. (Fall, Every year)

ECE 6250. ASIC Design and Testing of VLSI Circuits. 3 Credits.
ASIC design techniques, CAD tools. Logic synthesis, styles of synthesis, power/area/speed constraints. VLSI testing, fault models, design for testability, scan path, built-in self-test. Prerequisites: ECE 6240. Credit cannot be earned for this course and ECE 4150. (Spring, Every year)

ECE 6255. Sensors, Networks, and Applications. 3 Credits.
Sensor technologies for mechanical, optical, magnetic, electromagnetic, thermal, and acoustic signals; electronics Interface, calibration, noise, sensor networks. Permission of the instructor required prior to enrollment. Restricted to graduate students. Credit cannot be earned for this course and ECE 4155. (Spring, Every year)

ECE 6260. Introduction to Nanoelectronics. 3 Credits.
Nanoscience and technology and nanoelectronics. Basic nanofabrication steps of nanodevices, 2D materials. Use of tools for performing design and characterizations, in the clean room. Credit cannot be earned for this course and 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.
Theoretic principles of detecting and correcting errors in the transfer of information over digital communication channels. Emphasis on algebraic coding theory, and special linear block code classes and their performance bounds. Prerequisites: ECE 6015. (As arranged, 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 and fading countermeasures: coding, equalization. Power control. Cellular design and frequency reuse. Modulation and coding techniques. Spread Spectrum and OFDM. Random access methods. Code and Space Division Multiple Access, 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. Prerequisites: ECE 6510. (Fall, Even years)

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. (Summer, 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. Prerequisites: 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. Prerequisites: ECE 6015 and ECE 6035. (Fall, Every year)

ECE 6565. Network Security. 3 Credits.
Cryptographic techniques. Block and stream ciphers. The Advanced Encryption Standard (AES); key management, digital signatures, message authentication, hash functions; public key algorithms. Restricted to graduate students in a science or engineering field or with the permission of the instructor. (Fall, Every year)

ECE 6570. Telecommunications Security Protocols. 3 Credits.
The OSI security architecture: services and mechanisms; risk analysis; Internet protocol security 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, 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.
The course introduces students to the principles governing the design and implementation of various types of wireless networks; mathematical analysis of telecommunications traffic; technology of wireless information transmission systems; first, second and third generation cellular networks based on circuit and packet switching principles; capacity sharing and duplex transmission; Time Division and Code Division Multiplex system; fourth and fifth generation cellular networks; wireless local and personal area networks; performance evaluation of wireless cellular and local area networks. 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, power semiconductor converters. Renewable generation, utility grid integration, smart grid applications. Credit cannot be earned for this course and ECE 4610. (Spring, Every year)

ECE 6660. Electric Power Generation. 3 Credits.
Primary traditional/conventional and alternative/renewable energy sources and energy storage applications. Large generation plants and distributed generation units and impacts on transmission and distribution systems operation and infrastructure. (Fall, Every year)

ECE 6662. Power Electronics. 3 Credits.
The application of electronics to energy conversion; analysis, operation and control of power electronic circuits. General knowledge of electric circuits and linear control is required. Credit cannot be earned for this course and ECE 4662. (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. Prerequisites: ECE 6070. (Spring and fall, 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, control and regulatory aspects of nuclear power generation. (Fall, Even years)

ECE 6668. Power Distribution Grids. 3 Credits.
Equipment for power distribution. Switching and safety at the distribution voltage level. Bulk Insulation Level and Insulation coordination principles. Distribution-level "smart grid" innovations. Protective relays, fuses, ground-fault protection. Prerequisites: ECE 6070. (Fall, Odd years)

ECE 6669. Smart Power Grids. 3 Credits.
Overview of the smart grid definitions. Smart power generation. Smart power transmission technologies, monitoring, operation and control. Smart power distribution systems. Microgrids and distributed energy resources. Smart grid resilience. (Spring, Odd years)

ECE 6670. Power System Protection. 3 Credits.
Protection philosophy in power systems; protection systems and approaches; reliability and security of protection systems; protection of generators, transformers, motors, and transmission lines; protection requirements of distributed energy sources. (Spring, Even years)

ECE 6690. Power Systems Economics. 3 Credits.
Overview of power economics and market participants. Market clearing and ancillary service pricing; locational marginal and zonal pricing schemes; investments in generation and transmission; independent power producers. Prerequisites: ECE 6070. (As arranged, Every year)

ECE 6691. Power Systems Reliability. 3 Credits.
Overview of probability theory. Generation supply reliability techniques, modeling and evaluation; reliability assessment of interconnected systems; risk evaluation in power system operation; operating reserve techniques and indices. (Spring, Even years)

ECE 6699. Energy and Sustainability. 3 Credits.
Energy sources; consumptions; societal and environmental impacts; energy generation and harvesting technologies; thermodynamics and efficiency limits; emission and pollution; life-cycle-analysis; energy growth from an international perspective. Recommended background: A basic understanding of energy and thermodynamics such as material covered in ECE 4620 and MAE 2131. (As arranged, Every year)

ECE 6710. Microwave Engineering. 3 Credits.
Graduate level elective course open to Electrical Engineering graduate students. Topics include 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.
Graduate level elective course open to Electrical Engineering graduate students. Topics include 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. The course is intended to provide graduate students and engineers with an in-depth understanding of the fundamentals of remote sensing at microwave, infrared and optical frequencies with emphasis on recent research innovations in these areas. 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. (Fall and spring, 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. The course is intended to provide graduate students and engineers with an in-depth understanding of the fundamentals of wave propagation in complex media at microwave, infrared and optical frequencies with emphasis on recent research innovations in these areas. 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. Prerequisites: ECE 6020, ECE 6025, and ECE 6800. (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. (Fall and spring, 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. The course is intended to provide graduate students and engineers with an in-depth understanding of the fundamentals of wave propagation in complex media at microwave, infrared and optical frequencies with emphasis on recent research innovations in these areas. Offered as arranged. Prerequisite: ECE 6015. (Fall and spring, Every year)

ECE 6760. Propagation Modeling in Wireless Communications. 3 Credits.
Wireless communication channel modeling, propagation mechanisms, terrestrial fixed links, mobile satellite systems, macrocells, fading models, microcells, picocells, diversity, equalizers. Specific applications to 3G, 4G and 5G mobile systems. Prerequisite: ECE 6020. (Spring, Odd years)

ECE 6761. Light and Information. 3 Credits.
Optical theory and instrumentation with an emphasis on modern devices: image formation, wave optics, diffraction, interference; holography, optical computing, LIDAR technologies; intro to quantum optics, entanglement; information theory. Prerequisites: Working knowledge of introductory electromagnetism (Maxwell's equations and electromagnetic waves), vector calculus, and differential equations. Recommended background: Prior completion of ECE 3315 and ECE 4320. (Fall, Odd years)

ECE 6765. Photonics and Fiber Optics. 3 Credits.
Concepts of opto-electronic devices; light-matter interaction; laser, photodetector, modulator, waveguide, fiber; data modulation, speed; plasmonics and nanophotonics; industry perspective. Recommended background: Prior completion of at least one undergraduate course in electromagnetism and semiconductors. Credit cannot be earned for this course and ECE 4435. (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. (Summer, 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.
The objective of this course is to introduce computer processing of speech and audio. Topics include: acoustic sensor technologies and characteristics, direction fining, speech analysis and synthesis, audio formats and compression standards, time-varying autoregressive models, speech recognition, 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. Case studies and trials. Offered as arranged. Restricted to graduate students with programming experience in C, C++ or Java. Prerequisite: ECE 6005. (Fall and spring, Every year)

ECE 6820. Real-Time Digital Signal Processing. 3 Credits.
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: Students in this course should have taken at least one prior course in ECE 6005 Computer Architecture and Design and have a basic knowledge of computer architecture and DSP algorithms; Knowledge of C programming language, assembly language and MATLAB is desirable; If unsure, contact the instructor, and discuss the pre-requisite requirements. (Fall and 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 multi-rate sampling, z-transforms, responses of discrete systems, stability criteria, and discrete control design. Prerequisite: ECE 6010. (Fall, Odd years)

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. (Spring, Every year)

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 Tsypkin locus. Forced oscillations: jump resonance. Stability analysis: Liapunov criterion. Luré problem and Popov's method. Prerequisite: ECE 6010. (Fall, Even years)

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. Students should have completed at least one prior course in computational methods or signal processing, such as ECE 6800 or equivalent, prior to enrollment. Contact the instructor if uncertain as to whether this requirement has been met. Prerequisite: ECE 6800. (Spring, Odd years)

ECE 6842. Image Engineering. 3 Credits.
Solid-state imaging devices and image engineering; basic understanding of the detection and noise processes underlying the sensing of optical radiation and the engineering and physics of image formation; radiometry, optics and image formation, and imaging devices; image quality metrics and system design trades. Students should have completed at least one course in linear systems and stochastic processes prior to enrollment. Contact the instructor if uncertain as to whether this requirement has been met. (Fall, Even years)

ECE 6845. Image Synthesis. 3 Credits.
The objective of this course is to introduce techniques for synthesizing images using mathematical models and other reconstruction techniques. The course starts with introduction to image formation process, then other techniques for synthesizing color textures and three-dimensional scenes are covered. Prerequisite: ECE 6015. (Spring, Every year)

ECE 6850. Pattern Recognition and Machine Learning. 3 Credits.
Supervised learning: classification, regression. Bayes decision theory. Parametric, multivariate, nonparametric methods. Dimensionality reduction. Clustering, unsupervised learning. Decision trees. Perceptrons. Deep learning. Biomedical applications. Prerequisites: An undergraduate or graduate course in probability and in linear algebra; programming in any scientific language; or permission of instructor. Same As: BME 6850. (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. Current topics. 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: Huffman coding, run-length coding. Differential coding. Transform coding. Voice, audio, image and video coding techniques: CELP, JPEG, MPEG, MP3. Data coding standards: G.722, G.726, G.728, H.261, H.323. Offered as arranged. Prerequisites: ECE 6015 and ECE 6025. (Fall and spring, 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, least squares. Bayesian estimators. Wiener and Kalman filters, complex data and parameters. Applications to radar, speech, image, biomedicine, communications, controls. Prerequisite: ECE 6015. (Fall, Odd years)

ECE 6875. Wavelets and Their Applications. 3 Credits.
Time-frequency analysis. Multiresolution 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, 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 6882. Reinforcement Learning. 3 Credits.
Semi-supervised learning, sequential and automated decision making, dynamic programming, Monte Carlo learning, temporal difference learning, off-policy and on-policy learning, deep reinforcement learning, inverse reinforcement learning. (Spring, Every year)

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. Prerequisites: CSCI 6511; and ECE 6850. Recommended background: Students in this course should have taken at least one prior course in artificial intelligence and/or pattern recognition; Acceptable courses include ECE 6850 (Pattern Recognition), or an equivalent course; If unsure, contact the instructor, and discuss the pre-requisite requirements. Same As: BME 6885. (Spring, Even years)

ECE 6998. Thesis Research I. 3 Credits.
N/A.

ECE 6999. Thesis Research II. 3 Credits.
Thesis research.

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. 12 Credits.
May be repeated for credit. Restricted to doctoral candidates. (Fall and spring, Every year)