electrical and computer engineering (ECE) is a discipline that prepares graduates to solve problems across a diverse array of industries. Course work is drawn from a curriculum that includes cutting-edge ECE technologies: embedded systems and internet of things, robotics and cyber-human systems, networking (mobile/wireless as well as the internet of the future), and big data analytics and machine learning. Northeastern’s historic strengths in ECE include communications and digital signal processing, power and control systems, power electronics, RF/microwave magnetic materials, device technologies, computer engineering, networking, and robotics. The Department of Electrical and Computer Engineering is deeply committed to training and educating the next generation of electrical and computer engineers through Northeastern’s experiential learning model and comprehensive pedagogy. BS, MS, and PhD degrees are offered in both electrical and computer engineering.

Overview of Programs Offered
Please see the programs tab (p. 1) for a list of the department’s academic programs.

Successful engineers need to organize and adapt information to solve problems. They also must work effectively in teams and communicate well. Therefore, the goal of the electrical engineering and computer engineering programs is to help students develop these skills and provide the appropriate technical background for a successful career.

The curricula are continuously assessed to ensure that graduates can achieve these goals and go on to succeed as professional electrical or computer engineers. The Bachelor of Science programs allow students sufficient flexibility within the standard eight academic semesters to earn a minor in nearly any department in the university. Typical minors might include physics, math, computer science, or business, but students might also organize their course of study to earn a minor in economics, English, or music.

The academic program is supported by extensive laboratory facilities for study and experimentation in computing, circuit analysis, electronics, digital systems, microwaves, control systems, semiconductor processing, very large-scale integration (VLSI) design, and digital signal processing. Students have access to state-of-the-art computing facilities, including numerous Linux and Windows-based workstations. Many courses are taught in one of the four computer-based teaching classrooms. Two introductory electrical and computer engineering courses meet in integrated lab-classrooms where students and professors, assisted by undergraduate and graduate teaching assistants, work together on both theoretical and practical aspects of a wide range of signal processing and computing systems.

Mission of the Department
The primary educational missions of the Department of Electrical and Computer Engineering are to educate undergraduate students so they have the opportunity to obtain successful careers in electrical and computer engineering and related disciplines and pursue advanced study, such as graduate study in engineering or related disciplines, and to educate graduate students so they can make meaningful contributions to the research and industrial communities.

Other Programmatic Features
More than 90 percent of department undergraduates take advantage of the cooperative education program. During the cooperative work phase of the program, the students’ levels of responsibility grow as they gain theoretical and technical knowledge through academic work. A sophomore might begin cooperative work experience as an engineering assistant and progress by the senior year to a position with responsibilities similar to those of entry-level engineers.

The department also offers significant research opportunities throughout all fields of electrical and computer engineering, including participating in research centers based in our department and college.

A senior-year design course caps the education by drawing on everything learned previously. Teams of students propose, design, and build a functioning electrical or computer engineering system—just as they might in actual practice.

Programs
Bachelor of Science in Computer Engineering (BSCompE)
- Computer Engineering (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/computer-engineering-bscompe)
- Computer Engineering and Physics (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/computer-engineering-physics-bscompe)
- Computer Engineering and Computer Science (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/computer-engineering-computer-science-bscompe)

Bachelor of Science in Electrical Engineering (BSEE)
- Electrical Engineering (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-engineering-bsee)
- Electrical Engineering and Physics (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-engineering-physics-bsee)
- Electrical Engineering and Music with Concentration in Music Technology (http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-engineering-music-concentration-music-technology-bsee)
**Combined Major (BSEE or BSCompE)**

- Electrical and Computer Engineering ([http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-computer-engineering-bsee-bscompe](http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-computer-engineering-bsee-bscompe))

**Minors**

- Biomedical Engineering ([http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/biomedical-engineering-minor](http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/biomedical-engineering-minor))
- Computer Engineering ([http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/computer-engineering-minor](http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/computer-engineering-minor))
- Electrical Engineering ([http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-engineering-minor](http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/electrical-engineering-minor))
- Robotics ([http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/robotics-minor](http://catalog.northeastern.edu/undergraduate/engineering/electrical-computer/robotics-minor))

**Accelerated Programs**

See Accelerated Bachelor/Graduate Degree Programs ([http://catalog.northeastern.edu/undergraduate/engineering/accelerated-bachelor-graduate-degree-programs/#programstext](http://catalog.northeastern.edu/undergraduate/engineering/accelerated-bachelor-graduate-degree-programs/#programstext))

**Courses**

**Electrical and Computer Engineering Courses**

Search EECE Courses using FocusSearch ([http://catalog.northeastern.edu/course-search/?subject=EECE](http://catalog.northeastern.edu/course-search/?subject=EECE))

**EECE 1990. Elective. 1-4 Hours.**

Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

**EECE 2000. Introduction to Engineering Co-op Education. 1 Hour.**

Provides students preparation for the first co-op experience. Focuses on skills that provide a basis for successful co-op engagement including expectations and requirements, an introduction to professional credentials, résumé construction, self-assessment and goal setting, interviewing, professional and co-op ethics, issues of diversity in the workplace community, academic planning and decision making, and an introduction to career portfolios.

**EECE 2150. Circuits and Signals: Biomedical Applications. 5 Hours.**

Offers an integrated lecture/lab course that covers circuit theory, signal processing, circuit building, and MATLAB programming. Introduces basic device and signal models and circuit laws used in the study of linear circuits. Analyzes resistive and complex impedance networks. Uses the ideal operational amplifier model, focusing on differential amplifiers and active filter circuits. Introduces basic concepts of linearity and time-invariance for both continuous and discrete-time systems and concepts associated with analog/digital conversion. Demonstrates discrete-time linear filter design on acquired signals in the MATLAB environment. Offers students an opportunity to explore circuits and signals in the lab and to use their knowledge of circuits, analog signals, digital signals, and biological signals to build a working analog/digital EKG system.

**EECE 2160. Embedded Design: Enabling Robotics. 4 Hours.**

Offers an integrated lecture/lab course that covers the basics of the Unix operating system, high-level programming concepts, introductory digital design, wireless networking, and Simulink design. Offers students a hands-on experience developing a remote-controlled robotic arm using an embedded systems platform.

**EECE 2210. Electrical Engineering. 4 Hours.**

Introduces the basic concepts related to circuits and circuit elements; current, voltage, and power; models for resistors, capacitors, and inductors; and circuit analysis using Kirchhoff’s laws. Discusses selected topics that illustrate a variety of applications of electrical engineering, such as AC circuits and electric power, the basics of semiconductor devices with applications to transistor amplifier models, transients in circuits with energy storage, mechanical controls and mechatronics, digital signals, logic circuits, and some basic concepts of computer operations, specifically, number coding, arithmetic operations, and memory circuits.

**EECE 2211. Lab for EECE 2210. 1 Hour.**

Accompanies EECE 2210. Covers fundamental DC and AC electrical concepts as well as analog and digital electronics.

**EECE 2300. Computational Methods for Data Analytics. 4 Hours.**

Introduces the programming tools, algorithms, and software tools used in data analytics. Offers hands-on experience working with statistical software/packages and scripting languages and shows students the power of computational tools. Covers concepts of correlation, regression analysis, classification, and decomposition. Includes example data-oriented applications taken from multiple science/engineering disciplines and applies linear algebra and probability to analyze actual data sets. Students not meeting course prerequisites may seek permission of instructor.

**EECE 2322. Fundamentals of Digital Design and Computer Organization. 4 Hours.**

Covers the design and evaluation of control and data structures for digital systems. Uses hardware description languages to describe and design both behavioral and register-transfer-level architectures and control units. Topics covered include number systems, data representation, a review of combinational and sequential digital logic, finite state machines, arithmetic-logic unit (ALU) design, basic computer architecture, the concepts of memory and memory addressing, digital interfacing, timing, and synchronization. Assignments include designing and simulating digital hardware models using Verilog as well as some assembly language to expose the interface between hardware and software.

**EECE 2323. Lab for EECE 2322. 1 Hour.**

Offers students an opportunity to design and implement a simple computer system on field-programmable logic using a hardware description language. Covers simulation and testing of designs.

**EECE 2412. Fundamentals of Electronics. 4 Hours.**

Reviews basic circuit analysis techniques. Briefly introduces operation of the principal semiconductor devices: diodes, field-effect transistors, and bipolar junction transistors. Covers diode circuits in detail; the coverage of transistor circuits focuses mainly on large-signal analysis, DC biasing of amplifiers, and switching behavior. Uses PSpice software to simulate circuits and large-signal models and transient simulations to characterize the behavior of transistors in amplifiers and switching circuits. Digital electronics topics include CMOS logic gates, dynamic power dissipation, gate delay, and fan-out. Amplifier circuits are introduced with the evaluation of voltage transfer characteristics and the fundamentals of small-signal analysis.

**EECE 2413. Lab for EECE 2412. 1 Hour.**

Covers experiments reinforcing basic electronics topics such as diodes, bipolar junction transistors (BJT) as a switch, BJT amplifiers, and MOSFET circuits for switching and amplification. Practical measurements include use of voltmeters, ammeters, ohm meters, and impedance meters, as well as oscilloscope measurements of frequency, gain, distortion, and upper- and lower-cutoff frequencies of amplifiers.
EECE 2520. Fundamentals of Linear Systems. 4 Hours.
Develops the basic theory of continuous and discrete systems, emphasizing linear time-invariant systems. Discusses the representation of signals and systems in both the time and frequency domain. Topics include linearity, time invariance, causality, stability, convolution, system interconnection, and sinusoidal response. Develops the Fourier and Laplace transforms for the discussion of frequency-domain applications. Analyzes sampling and quantization of continuous waveforms (A/D and D/A conversion), leading to the discussion of discrete-time FIR and IIR systems, recursive analysis, and realization. The Z-transform and the discrete-time Fourier transform are developed and applied to the analysis of discrete-time signals and systems.

EECE 2530. Fundamentals of Electromagnetics. 4 Hours.
Introduces electromagnetics and high-frequency applications. Topics include transmission lines: transmission line model with distributed circuit elements, transmission line equations and solutions, one-dimensional traveling and standing waves, and applications; electromagnetic field theory: Lorentz force equations, Maxwell's equations, Poynting theorem, and application to the transmission line's TEM waves. Also studies uniform plane wave propagation along a coordinate axis and along an arbitrary direction; equivalent transmission lines for TEM, TE, and TM waves; reflection and refraction of uniform plane waves by conducting and dielectric surfaces. Discusses applications to wave guides, resonators, optical fibers, and radiation and elementary antennas. Introduces modern techniques (computational methods) and applications (optics, bioelectromagnetics, and electromagnetic effects in high-speed digital circuits).

EECE 2531. Lab for EECE 2530. 1 Hour.
Accompanies EECE 2530. Supports class material related to transmission lines, wave-guiding structures, plane wave reflection and refraction, and antenna radiation. Includes experiments with microwave transmission line measurements and the determination of the properties of dielectric materials, network analyzer analysis of microwave properties of circuit elements and transmission line electrical length, analysis of effective dielectric constant and loss from microstripline resonator transmission, optical measurement of refraction and reflection leading to determination of Brewster angle and optical constants for transparent and absorbing materials, and measurement of radiation patterns from dipole antennas.

EECE 2540. Fundamentals of Networks. 4 Hours.
Presents an overview of modern communication networks. The concept of a layered network architecture is used as a framework for understanding the principal functions and services required to achieve reliable end-to-end communications. Topics include service interfaces and peer-to-peer protocols, a comparison of the OSI (open system interconnection) reference model to the TCP/IP (Internet) and IEEE LAN (local area network) architectures, network-layer and transport-layer issues, and important emerging technologies such as Bluetooth and ZigBee.

EECE 2560. Fundamentals of Engineering Algorithms. 4 Hours.
Covers the design and implementation of algorithms to solve engineering problems using a high-level programming language. Reviews elementary data structures, such as arrays, stacks, queues, and lists, and introduces more advanced structures, such as trees and graphs and the use of recursion. Covers both the algorithms to manipulate these data structures as well as their use in problem solving. Introduces algorithm complexity analysis and its application to developing efficient algorithms. Emphasizes the importance of software engineering principles.

EECE 2750. Enabling Engineering. 4 Hours.
Offers students an opportunity to develop a proposal for a design project that uses engineering technologies to improve the lives of individuals with cognitive or physical disabilities. Offers student project groups an opportunity to work with end users and caregivers at local nursing homes and special education schools to assess a specific need, research potential solutions, and develop a detailed proposal for a project. Project groups are matched with product design mentors who guide groups through the design process. Lectures cover relevant topics, including surveys of specific physical and cognitive disabilities and applicable engineering technologies. The same project may not be used to satisfy both this course and EECE 4790. May be repeated up to two times.

EECE 2949. Introductory Directed Research in Electrical and Computer Engineering. 4 Hours.
Offers first- and second-year students an opportunity to pursue project and other independent inquiry opportunities under faculty supervision. The course is initiated with a student-developed proposal, including expected learning outcomes and research products, which is approved by a faculty member in the department. Requires permission of instructor.

EECE 2990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

EECE 3000. Professional Issues in Engineering. 1 Hour.
Provides students with an opportunity to reflect on both academic and co-op experiences in the context of planning for the senior year and beyond. Issues include professional and ethical issues, resolving ethical conflicts, awareness of engineers as professionals in a diverse world, strengthening decision-making skills, career portfolios, and lifelong learning needs, goals, and strategies. Students reflect upon issues of diversity from their experience in the University and in their cooperative education placements. Explores the role of different work and learning styles and diverse personal characteristics on the workplace and the classroom. Professional issues include impact of the cultural context, both in the United States and around the world, on the client, government relations, and the workplace.

EECE 3324. Computer Architecture and Organization. 4 Hours.
Presents a range of topics that include assembly language programming, number systems, data representations, ALU design, arithmetic, the instruction set architecture, and the hardware/software interface. Offers students an opportunity to program using assembly language and to simulate execution. Covers the architecture of modern processors, including datapath/control design, caching, memory management, pipelining, and superscalar. Discusses metrics and benchmarking techniques used for evaluating performance.

EECE 3392. Electronic Materials. 4 Hours.
Provides a basic treatment of electronic materials from atomic, molecular, and application viewpoints. Topics include atomic structure and bonding in materials, structure of materials, and crystal defects. These topics lay a foundation for the introduction of thermal and electronic conduction, which is the underlying physics of electronic devices. Finally, the electronic properties of semiconductors, dielectric, magnetic, superconducting, and optical materials are examined. The latter half deals with an introduction to the state of the art in electronic materials, including semiconductor nanoelectronics, magnetic semiconductors and spintronics, molecular electronics, carbon nanotubes, conducting polymers, diamondlike carbon, and other topics representing recent technological breakthroughs in the area of electronic materials.
EECE 3410. Electronics 2. 4 Hours.
Covers transistors and op-amp circuits. Emphasizes real devices and their performance, analog IC design concepts, and building blocks. Reviews the Laplace transform and introduces its applications to analysis of electronic circuits governed by linear differential equations. Presents and employs equivalent models of passive and active elements in s-domain analysis including response speed, pole/zero plots, and magnitude/phase frequency behavior of important network functions. Introduces feedback and stability, oscillators, A/D and D/A converters and mixed-signal circuits, active filters, sensors and signal-conditioning circuits, and other design topics at the discretion of the instructor. Uses SPICE simulation to support design work. Includes laboratory hardware projects.

EECE 3468. Noise and Stochastic Processes. 4 Hours.
 Discusses probability, random variables, random processes, and their application to noise in electrical systems. Begins with the basic theory of discrete and continuous probabilities, then develops the concepts of random variables, random vectors, random sequences, and random processes. Continues with a discussion on the physical origins of noise and models of where it is encountered in electronic devices, signal processing, and communications. Defines the concepts of correlation, covariance, and power density spectra and uses them to analyze linear system operations in continuous time.

EECE 3990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

EECE 4512. Healthcare Technologies: Sensors, Systems, and Analysis. 4 Hours.
Examines healthcare technologies using both theory and hands-on approaches. Testing, imaging, and data collection are essential tools medical specialists use to treat patients and the primary contribution of engineers to healthcare. Covers the physics and physiology behind the newly defined concept of digital biomarkers; the electronics needed to collect these biomarkers; analysis techniques for processing and interpreting the data; and invasive (swallowable/implantable), on-body (wearable), and contactless systems for data collection. Examines safety issues, ethics, and regulatory hurdles from both an industry and research perspective. In the hands-on labs, offers students an opportunity to follow the steps of creating a startup or conducting new research and assembling a microcontroller-based sensor system for collecting digital biomarkers.

EECE 4520. Software Engineering 1. 4 Hours.
Offers an overview of the discipline of software engineering. Identifies the problems that one should expect when developing large software systems; methods that the software developer can use to deal with each of the problems; tools that the software developer can use; and procedures that can be followed in developing software. Covers the software life cycle (requirements analysis and specification, software design, coding, testing, and maintenance); various models of the software process—structured and agile; the Unified Modeling Language (UML) as applied to the software life cycle, prototyping, and documentation; design patterns; software metrics and estimation; software development environments and tools; and verification and validation. Includes a software development project that covers all the stages of the life cycle.

EECE 4524. VLSI Design. 4 Hours.
Covers a structured digital CMOS design focusing on designing, verifying, and fabricating CMOS VLSI-integrated circuits and modules. Emphasizes several topics essential to the practice of VLSI design as a system design discipline including systematic design methodology, good understanding of CMOS transistor, physical implementation of combinational and sequential logic network, and physical routing and placement issues. Begins design exercises and tutorials with basic inverters and proceeds to the design, verification, and performance of large, complex digital logic networks. Also covers IC design methodologies and performance, scaling of MOS circuits, design and layout of subsystems such as PLA and memory, and system timing. Requires lab session that includes computer exercises using CAD tools to design VLSI layouts and switch-level plus circuit-level simulations to design and analyze the project.

EECE 4525. Lab for EECE 4524. 1 Hour.
Accompanies EECE 4524. Covers topics from the course through various experiments.

EECE 4534. Microprocessor-Based Design. 4 Hours.
Focuses on the hardware and software design for devices that interface with embedded processors. Topics include assembly language; addressing modes; embedded processor organization; bus design; electrical characteristics and buffering; address decoding; asynchronous and synchronous bus protocols; troubleshooting embedded systems; I/O port design and interfacing; parallel and serial ports; communication protocols and synchronization to external devices; hardware and software handshake for serial communication protocols; timers; and exception processing and interrupt handlers such as interrupt generation, interfacing, and auto vectoring.

EECE 4535. Lab for EECE 4534. 1 Hour.
Accompanies EECE 4534. Consists of a comprehensive laboratory performed by a team of students. These laboratory exercises require students to design, construct, and debug hardware and software that runs on an embedded platform. Exercises are centered around a common embedded platform. The final exercise is a project that lets each group integrate hardware and software to realize a complete embedded design.

EECE 4542. Advanced Engineering Algorithms. 4 Hours.
Covers classical and modern algorithms that efficiently solve hard electrical and computer engineering optimization problems. These problems arise in a wide range of disciplines—including computer-aided design, parallel computing, computer architecture, and compiler design—and are usually NP-complete, making it unlikely that optimal solutions can be found in a reasonable amount of time. Covers the fundamentals of algorithm analysis and complexity theory and then surveys a wide range of combinatorial optimization techniques, including exhaustive algorithms, greedy algorithms, integer and linear programming, branch and bound, simulated annealing, and genetic algorithms. Considers the efficient generation of optimal solutions, the development and evaluation of heuristics, and the computation of tight upper and lower bounds.
EECE 4572. Communications Systems. 4 Hours.
Introduces basic concepts of digital communication over additive white Gaussian noise (AWGN) channels. Reviews frequency domain signal analysis through treatment of noiseless analog communication. Reviews foundations of stochastic processes including stationarity, ergodicity, autocorrelation, power spectrum, and filtering. Provides an introduction to lossless and lossy source coding and introduces Huffman and Lempel-Ziv algorithms. Introduces optimal quantization and PCM and DPCM systems. Examines geometric representation of signals and signal space concepts, principles of optimum receiver design for AWGN channels, correlation and matched filter receivers, and probability of error analysis for binary and M-ary signaling through AWGN channels, and performance of ASK, PSK, FSK, and QAM signaling schemes. If time permits, also covers digital PAM transmission through band-limited AWGN channels, zero ISI condition, system design in the presence of channel distortion, and equalization techniques.

EECE 4574. Wireless Communication Circuits. 4 Hours.
Covers the electronics of radio receivers and transmitters. Employs a commercial radio transceiver (MF-J-9340) as a learning tool. Presents basic topics (radio spectrum and its utilization, antennae, and information processing by modulation and demodulation). Studies building block realizations for modulators and demodulators for analog (AM, FM) and digital (ASK, PSK, FSK) radio. Covers common radio receiver architectures. Presents circuit-level designs of radio building blocks (resonators; L-C RF filters; crystals and IF filters; tuned transformers and impedance matching; amplifiers and power amplifiers; RF oscillators; mixers and up/down frequency conversion; signal detectors; and automatic gain control circuits). Includes receiver noise and sensitivity; transmitter range; spurious emissions and IM distortion; antennae and propagation in the atmosphere; wireless standards; multiple-access techniques; and software-defined radio. May include additional topics at instructor’s discretion.

EECE 4604. Integrated Circuit Devices. 4 Hours.
Offers a comprehensive introduction to the technology, theory, and applications of the most important electronic devices in today's integrated circuits. Topics include semiconductor electronic properties, Si fabrication technologies, p-n junctions, MOS capacitors, MOSFETS, metal-semiconductor contacts, and bipolar transistors. Emphasizes MOS devices, which are currently the dominant technology in integrated circuits. Introduces recent research trends in novel device concepts. Offers students who may pursue semiconductor process engineering, IC design, biomedical electronics, or research and development of microelectromechanical systems (MEMS) or optoelectronics devices an opportunity to obtain electronic device knowledge.

EECE 4626. Image Processing and Pattern Recognition. 4 Hours.
Provides an introduction to processing and analysis of digital images with the goal of recognition of simple pictorial patterns. Topics include discrete signals and systems in 2-D, digital images and their properties, image digitization, image enhancement, image restoration, image segmentation, feature extraction, object recognition, and pattern classification principles (Bayes rules, class boundaries) and pattern recognition methods.

EECE 4630. Robotics. 4 Hours.
Introduces robotics analysis covering basic theory of kinematics, dynamics, and control of robots. Develops students' design capabilities of microprocessor-based control systems with input from sensory devices and output actuators by having teams of students design and implement a small mobile robot system to complete a specific task, culminating in a competition at the end of the course. Covers actuators, sensors, system modeling, analysis, and motion control of robots.

EECE 4638. Special Topics in Computer Engineering. 4 Hours.
Focuses on advanced topics related to computer engineering technology to be selected by instructor. May be repeated without limit.

EECE 4642. Antennas. 4 Hours.
Introduces the fundamental physical principles for the electromagnetic radiation from antennas and presents the most important mathematical techniques for the analysis of the radiation. Applies these principles and techniques to practical antenna systems. Starts with the fundamental parameters of the antennas. Introduces the vector potentials and the theorems that are needed for the derivation of the radiation integrals from Maxwell's equations. Covers the application of these theories to practical antennas and antenna systems, including linear wire antennas, loop antennas, linear and two-dimensional planar phased arrays, patch antennas, frequency-independent antennas, and aperture and reflector antennas. Presents impedance matching techniques.

EECE 4646. Optics for Engineers. 4 Hours.
Presents the basic optical concepts necessary for an understanding of current and future optical communication, remote sensing, and industrial and biomedical systems. Topics include geometrical optics, polarized light, diffraction, and interference. Studies lasers and other light sources, optical fibers, detectors, CCD cameras, modulators, and other components of optical systems. Presents applications to specific systems such as fiber-optic communication, medical imaging systems, fiber-optic sensors, and laser radar.

EECE 4649. Biomedical Imaging. 4 Hours.
Explores a wide variety of modalities for biomedical imaging in the pathology laboratory and in vivo. After an introductory discussion of tissue properties, waves used in imaging, and contrast mechanisms, the course discusses modalities such as microscopy, endoscopy, x-ray, computed tomography, ultrasound, and MRI. With each modality, instrument parameters, contrast mechanisms, resolution, and depth of penetration are considered. Offers students an opportunity to work in groups to complete a project in which they examine one modality in detail and either generate synthetic data using a computational model or process available image data.

EECE 4688. Detection of Signals in Noise. 4 Hours.
Introduces topics of signal detection, estimation, and related signal processing algorithms. Extraction of signals and useful information from noise is a fundamental problem encountered in engineering disciplines ranging from traditional communications and control to biomedical engineering, security and defense, and reaching into financial analysis. Addresses concepts such as hypothesis testing, Bayesian principles, likelihood functions, sufficient statistics, and minimum mean squared error estimation of signals with known as well as unknown parameters. Lectures are supported by illustrative examples and hands-on exercises, which rely on the use of MATLAB and are grounded in practical problems.

EECE 4694. Numerical Methods and Computer Applications. 4 Hours.
Presents numerical techniques used in solving scientific and engineering problems with the aid of digital computers. Topics include theory of interpolation; the theory of numerical integration and differentiation, numerical solutions of linear as well as nonlinear systems of equations, the theory of least squares; and numerical solution of ordinary and partial differential equations using a programming environment such as MATLAB.
EECE 4790. Electrical and Computer Engineering Capstone 1. 4 Hours.
Requires students to select a project requiring design and implementation of an electrical, electronic, and/or software system, form a team to carry out the project, and submit and present a detailed proposal for the work. Students must specify the materials needed for their project, provide cost analysis, and make arrangements with their capstone adviser to purchase and/or secure donation of equipment. Requires student to perform a feasibility study by extensive simulation or prototype design of subsystems to facilitate the second phase of the capstone design.

EECE 4792. Electrical and Computer Engineering Capstone 2. 4 Hours.
Continues EECE 4790. Requires students to design and implement the project proposed in that earlier course. Expects students to evaluate progress with interim milestone reports and to present the final design project with written and oral reports.

EECE 4949. Research Laboratory Project. 4 Hours.
Offers an opportunity to conduct research in a laboratory setting under faculty supervision. May be repeated once.

EECE 4990. Elective. 1-4 Hours.
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

EECE 4991. Research. 4 Hours.
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

EECE 4992. Directed Study. 1-4 Hours.
Offers independent work under the direction of members of the department on a chosen topic. Course content depends on instructor. May be repeated without limit.

EECE 4993. Independent Study. 1-4 Hours.
Offers theoretical or experimental work under individual faculty supervision. May be repeated without limit.

EECE 5115. Dynamical Systems in Biological Engineering. 4 Hours.
Provides an introduction to the theoretical analysis and modeling of dynamical systems in biology, ranging from molecular to population applications. Topics include difference and differential equation models, with basic theory including nondimensionalization, steady states, linearization, stability, eigenvalues, global behavior, singular perturbations, multiscale dynamics, hysteresis, cooperativity, periodic solutions, excitable systems, bifurcations, and an introduction to spatial (PDE) models. Develops all concepts in the context of concrete biological applications, such as gene regulation, chemical reaction networks and stoichiometry, drug models and PK/PD, receptor/ligand interactions, synthetic constructs, action potential generation, enzymatic reactions, population interactions, epidemiology, epigenetic phenomena including differentiation, and transport, chemotaxis, and diffusion. BIOE 5115 and EECE 5115 are cross-listed.

EECE 5155. Wireless Sensor Networks and the Internet of Things. 4 Hours.
Covers design and modeling of architectures, communication protocols, and algorithms for wireless sensor networks. The first part of the course covers general aspects of wireless sensor networking, including protocol design, modeling, and simulation at all layers of the communication stack. The second part covers standardization efforts, including Bluetooth, IEEE 802.15.4 and Zigbee, RFID, 6LoWPan, and Internet of Things, among others. The third part covers applications of sensor networks technology to many challenging problems of our time, including cyber-physical systems, smart cities, smart transportation systems, and underwater sensing systems.

EECE 5161. Thin Film Technologies. 4 Hours.
Covers the fundamentals of vacuum technology, thin film deposition technologies, characterization technologies, their applications in different industries, and the frontiers of research activities on thin film deposition technologies. Thin films are fundamental building blocks for integrated circuits chips, microelectromechanical systems (MEMS) devices, and nanoelectromechanical system devices (NEMS), etc., and play critical roles in determining the performance of IC circuits, MEMS, and NEMS devices. Topics include vacuum technologies; vacuum pumps; vacuum system design and analysis; different thin film deposition technologies, including sputtering, chemical vapor deposition, electrochemical deposition, atomic layer deposition, etc.; and different thin film characterization technologies, in particular the magnetic thin film characterization technologies, including VSM, PPMS, FMR, MOKE, etc. Students who do not meet course prerequisites may seek permission of instructor.

EECE 5170. Introduction to Multiferroics Materials and Systems. 4 Hours.
Offered by the NSF Nanosystems Engineering Research Center for Translational Applications of Nanoscale Multiferroic Systems (TANMS) and co-taught by professors from UCLA, UC Berkeley, Cornell, California State University Northridge, and Northeastern University. Course lectures will be available online for remote students. Covers introduction to multiferroics, atomic structure of multiferroics (chemistry), multiferroic material science, continuum-level analysis of multiferroic materials, and multiferroic devices.

EECE 5550. Mobile Robotics. 4 Hours.
Investigates the science and engineering of mobile robots. Topics may include kinematics, dynamics, numerical methods, state estimation, control, perception, localization and mapping, and motion planning for mobile robots. Emphasizes practical robot applications ranging from disaster response to healthcare to space exploration.

EECE 5552. Assistive Robotics. 4 Hours.
Investigates the what (modeling), how (design), and why (analysis) of assistive robotics through the use of model-based design process. System models are essential to four key aspects of the assistive robot design process: derivation of executable specifications, hardware and software design based on simulations, implementation by code generation, and continuous testing and verification. Topics may include modeling continuous and discrete dynamics, heterogeneous models, hybrid systems, stochastic models, models of computation, analysis and design of embedded control systems with applications in assistive robotics, system simulation, and validation and verification techniques. Course projects emphasize model-based design for control of assistive robots in smart environments.

EECE 5554. Robotics Sensing and Navigation. 4 Hours.
Examines the actual sensors and mathematical techniques for robotic sensing and navigation with a focus on sensors such as cameras, sonars, and laser scanners. These are used in association with techniques and algorithms for dead reckoning and visual inertial odometry in conjunction with GPS and inertial measurement units. Covers Kalman filters and particle filters as applied to the SLAM problem. A large component of the class involves programming in both the ROS and LCM environments with real field robotics sensor data sets. Labs incorporate real field sensors and platforms. Culminates with both an individual design project and a team-based final project of considerable complexity.
EECE 5576. Wireless Communication Systems. 4 Hours.
Examines fundamental principles of wireless system design, focusing on modern techniques used in cellular systems and wireless local area networks. Covers various levels of system design, from modulation/detection to traffic analysis. Introduces basics of radio propagation and studies their effect on communication signals. Special topics include spatial frequency reuse; call blocking and cellular system capacity; power control and hand-off strategies; channel access and sharing; orthogonal frequency division multiplexing (OFDM—a modulation technique used in WLAN and the fourth-generation [4G] cellular systems) and spread spectrum modulation (third-generation WCDMA systems); diversity techniques and multi-input multi-output (MIMO) signal processing. Requires an undergraduate course in communications systems.

EECE 5580. Classical Control Systems. 4 Hours.
Introduces the analysis and design of classical control systems. Examines control system objectives, modeling and mathematical description, transfer function and state-variable representations, feedback control system characteristics, system responses, and stability of feedback systems. Also addresses compensator design based on root-locus and frequency response, and modern control system design using state-variable feedback. Requires concurrent registration in EECE 5581 for undergraduate students.

EECE 5581. Lab for EECE 5580. 1 Hour.
Accompanies EECE 5580. Covers the practical aspects of control systems design through lab experiments. Topics vary and include computer simulation, digital computer control, and use of CAD packages such as MATLAB for analysis and design of control systems. Examples emphasize concepts introduced in EECE 5580, such as system response to stimuli, stability, and robustness. Requires concurrent registration in EECE 5580.

EECE 5586. Micro- and Nanofabrication. 4 Hours.
Provides an overview of integrated circuit fabrication from the viewpoint of a process engineer. Offers students an opportunity to fabricate micro- and nanoscale devices in integrated lab sessions. Focuses on the physics, chemistry, and technology of integrated circuit fabrication in the lecture portion of the course, while students fabricate and test novel devices (an electrohydrodynamic micropump and three-dimensional carbon nanotube interconnects) in integrated lab sessions. Concentrates on silicon IC technology but also includes examples from other materials and device systems including microelectromechanical (MEMS) technologies that are used to build devices such as accelerometers, pressure sensors, and switches for telecommunications and other current examples provided from nanofabrication and nanotechnology. Lab hours are arranged.

EECE 5601. Digital Control Systems. 4 Hours.
Covers sampling and analysis tools for linear discrete-time dynamic systems, including the design of digital control systems using transform techniques by discrete equivalent and direct design methods; root locus, Bode and Nyquist diagrams, and Nichols charts; controller implementation issues, such as digital filter realizations, nonlinear effects due to quantization, round off, dead band, and limit cycles; and selection of the sampling rate.

EECE 5625. Image Processing and Pattern Recognition. 4 Hours.
Introduces processing and analysis of digital images with the goal of recognition of simple pictorial patterns. Topics include discrete signals and systems in 2D, digital images and their properties, image digitization, image enhancement, image restoration, image segmentation, feature extraction, object recognition, and pattern classification principles (Bayes rules, class boundaries) and pattern recognition methods.

EECE 5627. Arithmetic and Circuit Design for Inexact Computing with Nanoscaled CMOS. 4 Hours.
Studies the principles of inexact (approximate) computing through arithmetic and circuit design. By reducing circuit complexity, critical path delay, and power dissipation at the expense of introducing processing errors in computation, inexact computing is one of the leading emerging paradigms in nanoscale computing. Topics include basic computer arithmetic, approximation criteria, error analysis, nanoscale CMOS principles (PTMs), case studies, and experimental assessment.

EECE 5638. Compilers for Modern Computer Architectures. 4 Hours.
Covers the structure and implementation of a modular compiler. The first half of the course focuses on the compiler front end, based on a lexical analyzer, syntax parser, and intermediate code generator. The second part deconstructs a compiler back end, based on structural analysis, multistage optimizations, and assembly code generation. Topics include practical examples based on LLVM, a popular intermediate language specification and tool chain. Includes a series of tightly related assignments, which guide students through the implementation of a fully functional LLVM-based compiler from the ground up. The resulting project is a tool capable of interpreting a subset of the C programming language and generating an executable program represented with MIPS assembly code.

EECE 5639. Computer Vision. 4 Hours.
Introduces topics such as image formation, segmentation, feature extraction, matching, shape recovery, dynamic scene analysis, and object recognition. Computer vision brings together imaging devices, computers, and sophisticated algorithms to solve problems in industrial inspection, autonomous navigation, human-computer interfaces, medicine, image retrieval from databases, realistic computer graphics rendering, document analysis, and remote sensing. The goal of computer vision is to make useful decisions about real physical objects and scenes based on sensed images. Computer vision is an exciting but disorganized field that builds on very diverse disciplines such as image processing, statistics, pattern recognition, control theory, system identification, physics, geometry, computer graphics, and learning theory. Requires good programming experience in Matlab or C++.

EECE 5640. High-Performance Computing. 4 Hours.
Covers accelerating scientific and other applications on computer clusters, many-core processors, and graphical processing units (GPUs). Modern computers take advantage of multiple threads and multiple cores to accelerate scientific and engineering applications. Topics covered include parallel computer architecture, parallel programming models, and theories of computation, as well as models for many-core processing. Highlights implementation of computer arithmetic and how it varies on different computer architectures. Includes an individual project where each student is expected to implement an application, port that application to several different styles of parallelism, and compare the results. Programming is done in variants of the C programming language.

EECE 5641. Introduction to Software Security. 4 Hours.
Offers students an opportunity to learn how the security of systems can be violated and how such attacks can be detected and prevented. Computer security problems have a significant impact on practical aspects of our lives. Despite a considerable corpus of knowledge about tools and techniques to protect systems, information about actual vulnerabilities and how they are exploited is not generally available. Covers common programming, configuration, and design mistakes and examines possible protection and detection techniques. Uses examples to highlight general error classes. Includes a number of practical lab assignments that require students to apply their knowledge, as well as engage in a discussion of the current research in the field.
EECE 5642. Data Visualization. 4 Hours.
Introduces relevant topics and concepts in visualization, including computer graphics, visual data representation, physical and human vision models, numerical representation of knowledge and concept, animation techniques, pattern analysis, and computational methods. Topics include tools and techniques for practical visualization and elements of related fields, including computer graphics, human perception, computer vision, imaging science, multimedia, human-computer interaction, computational science, and information theory. Covers examples from a variety of scientific, medical, interactive multimedia, and artistic applications. Includes hands-on exercises and projects. Emphasizes modern engineering applications of computer vision, graphics, and pattern classification methodologies for data visualization.

EECE 5643. Simulation and Performance Evaluation. 4 Hours.
Studies simulation and performance evaluation in computer systems. Primarily covers both classic and timely techniques in the area of performance evaluation, including capacity planning to predict system performance, scheduling, and resource allocation in computer systems. Introduces basic computational and mathematical techniques for modeling, simulating, and analyzing the performance by using simulation, including models, random-number generation, statistics, and discrete event-driven simulation.

EECE 5644. Introduction to Machine Learning and Pattern Recognition. 4 Hours.
Studies machine learning (the study and design of algorithms that enable computers/machines to learn from experience/data). Covers a range of algorithms, focusing on the underlying models between each approach. Emphasizes the foundations to prepare students for research in machine learning. Topics include Bayes decision theory, maximum likelihood parameter estimation, model selection, mixture density estimation, support vector machines, neural networks, probabilistic graphics models, and ensemble methods (boosting and bagging). Offers students an opportunity to learn where and how to apply machine learning algorithms and why they work.

EECE 5645. Parallel Processing for Data Analytics. 4 Hours.
Covers the fundamentals of parallel machine-learning algorithms, tailored specifically to learning tasks involving large data sets. Reviews methods for dealing with both large and high-dimensional data sets, emphasizing distributed implementations. Beyond covering the theory behind statistical data analysis, the course also offers a hands-on approach, using Spark as a development platform for parallel learning. Topics include Apache Spark fundamentals, multithreaded/cluster execution, resilient distributed data structures, map-reduce operations, using key-value pairs, joins, convex optimization, gradient descent, linear regression, Gauss-Markov theorem, ridge and lasso regularization, feature selection, cross validation, variance vs. bias trade-off, classification, logistic regression, ROC curves and AUC, matrix and tensor factorization, graph-parallel algorithms and sparsity, Perceptron algorithm, and deep neural networks.

EECE 5647. Nanophotonics. 4 Hours.
Introduces basic concepts and recent developments in nanophotonic materials and devices. Nanophotonics is one very important research area in nanotechnology. Discusses the fundamentals of electromagnetics (Maxwell’s equations, polarization, wave propagations, etc.); quantum mechanics; and typical nanofabrication and characterization techniques. Focuses on specific topics in nanophotonics, including silicon photonics; photonic crystals; plasmonics and optical metamaterials, with their diverse applications in optical circuits; imaging; optical trapping; biomedical sensing; and energy harvesting. Offers students an opportunity to obtain a fundamental understanding of the property and manipulation of light at the nanoscale.

EECE 5649. Design of Analog Integrated Circuits with Complementary Metal-Oxide-Semiconductor Technology. 4 Hours.
Covers theoretical analysis, practical design, and simulation of analog integrated circuits implemented in complementary metal-oxide-semiconductor (CMOS) fabrication process technologies. Introduces cadence tools for circuit simulations, physical layout, and layout verification. Begins with basic concepts such as CMOS device models, DC and small-signal analysis techniques for single- and multistage amplifiers, biasing configurations, and reference generation circuits. Explores differential signal processing, operational amplifiers, operational transconductance amplifiers, and common-mode feedback circuits. Analysis methods include the evaluation of linearity, noise, stability, and device mismatches from process variations. Addresses some advanced design techniques, such as linearization improvement methods, frequency compensation, and digitally assisted performance tuning.

EECE 5652. Microwave Circuits and Networks. 4 Hours.
Addresses novel applications of analytical and engineering techniques for RF/Microwave Circuits. Covers transmission lines, impedance matching, S-parameters, high-frequency circuit analysis, power dividers, resonators, and filters. Emphasizes presenting fundamental concepts, essential mathematical formulas and theorems, and engineering applications. Provides ample examples to ensure participants are given an opportunity to fully appreciate the power of the techniques described and to gain extensive experience in the area of high-frequency circuits, from theory formulation to novel engineering designs.

EECE 5666. Digital Signal Processing. 4 Hours.
Presents the theory and practice of modern signal processing techniques. Topics include the characteristics of discrete signals and systems, sampling, and A/D conversion; the Z-transform, the Fourier transform, and the discrete Fourier transform; fast Fourier transform algorithms; design techniques for IIR and FIR digital filters; and quantization effects in digital signal processing. Graduate students may register for this course only if they did not complete an undergraduate course in digital signal processing; such graduate registration requires approval of instructor and an internal departmental petition.

EECE 5680. Electric Drives. 4 Hours.
Examines all subsystems that comprise an electric drive including electric machines, power electronic converters, mechanical system requirements, feedback controller design, and interactions with utility systems. Based on an integrative approach that requires minimal prerequisites: a junior-level course in signals and systems and some knowledge of electromagnetic field theory (possibly from physics classes), and does not require separate courses in electric machines, controls, or power electronics.

EECE 5681. Lab for EECE 5680. 0 Hours.
Accompanies EECE 5680. Covers topics from the course through various experiments.

EECE 5682. Power Systems Analysis 1. 4 Hours.
Covers fundamentals including phasors, single-phase and balanced three-phase circuits, complex power, and network equations; symmetrical components and sequence networks; power transformers, their equivalent circuits, per unit notation, and the sequence models; transmission line parameters including resistance, inductance, and capacitance for various configurations; steady-state operation of transmission lines including line loadability and reactive compensation techniques; power flow studies including Gauss-Newton Raphson interactive schemes; symmetrical faults including formation of the bus impedance matrix; and unsymmetrical faults including line-to-ground, line-to-line, and double line-to-ground faults.
**EECE 5684. Power Electronics. 4 Hours.**
Provide tools and techniques needed to analyze and design power conversion circuits that contain switches. The first part of the course emphasizes understanding and modeling of such circuits, and provides a background for engineering evaluation of power converters. The second part covers dynamics and control of this class of systems, enabling students to design controllers for a variety of power converters and motion control systems. Addresses a set of analytical and practical problems, with emphasis on a rigorous theoretical treatment of relevant questions. Designed for students with primary interests in power conditioning, control applications, and electronic circuits, but it could prove useful for designers of high-performance computers, robots, and other electronic and electromechanical (mechatronic) systems in which the dynamical properties of power supplies become important.

**EECE 5685. Lab for EECE 5684. 0 Hours.**
Accompanies EECE 5684. Covers topics from the course through various experiments.

**EECE 5686. Electrical Machines. 4 Hours.**
Reviews phasor diagrams and three-phase circuits; the magnetic aspects including magnetic circuits and permanent magnets; transformers, their equivalent circuits, and performance; principles of electromechanical energy conversion; elementary concepts of rotating machines including rotating magnetic fields; and steady-state theory and performance of induction machines, synchronous machines, and direct current machines.

**EECE 5688. Analysis of Unbalanced Power Grids. 4 Hours.**
Examines common types of power system faults. Starts with a detailed description of three-phase modeling of basic power system elements such as transmission lines, transformers, and generators. Then presents fundamentals of three-phase circuit analysis in the steady state, both for balanced and unbalanced operating conditions. Uses symmetrical component transformation and positive, negative, and zero sequence networks to analyze unbalanced systems. Presents methods to calculate fault currents and postfault bus voltages. Reviews basic protective relaying and relay settings using typical distribution system examples.

**EECE 5697. Acoustics and Sensing. 4 Hours.**
Introduces the fundamental concepts of acoustics and sensing with waves. Offers a unified theoretical approach to the physics of image formation through scattering and wave propagation in sensing. Topics include the linear and nonlinear acoustic wave equation; sources of sound; reflection, refraction, transmission, and absorption; bearing and range estimation by sensor array processing, beam forming, matched filtering, and focusing; diffraction, bandwidth, ambient noise, and reverberation limitations; scattering from objects, surfaces, and volumes by Green's theorem; forward scatter, shadows, Babinet's principle, extinction, and attenuation; ray tracing and waveguides in remote sensing; and applications to acoustic, radar, seismic, thermal, and optical sensing and exploration.

**EECE 5698. Special Topics in Electrical and Computer Engineering. 4 Hours.**
Covers special topics in electrical and computer engineering. Topics are selected by the instructor and vary from semester to semester. May be repeated up to four times.