ELECTRICAL AND COMPUTER ENGINEERING

Our Website (http://www.ece.vt.edu)

Overview

The Bradley Department of Electrical and Computer Engineering (ECE) offers bachelor of science degrees in electrical engineering (EE) and computer engineering (CPE). A key competitive advantage offered to undergraduate students in the department is the ability of students to pursue one of twelve different majors. This is possible since the department is one of the largest ECE departments in the U.S. with faculty expertise across the spectrum of electrical and computer engineering.

Traditional electrical and computer engineering programs consist of five basic areas: electricity (e.g. power systems), electronics, electromagnetics, hardware, and software. Graduates today apply their degree in more varied careers from investment banks to NGOs to medical firms. Instead of pushing student onto a single path, the department model allows students to choose the course of study that reflects their personal goals. Students have the flexibility to make conscious choices about what to do next at every stage of their journey.

All students in the department go through a seven-course base curriculum during their second year and then branch into their choice of major. This approach reflects today's reality that the electrical and computer engineers create technology that is transforming modern life – from transportation, agriculture, and manufacturing, to healthcare, education, entertainment, and social interactions. Students pursuing an electrical engineering degree can select a major from Controls, Robotics & Autonomy, Wireless Communications & Signal Processing, Energy & Power Electronic Systems, Micro/Nanosystems, and Applied Electromagnetics. Students pursuing a computer engineering degree can select a major from Chip-Scale Integration, Machine Learning, Networking & Cybersecurity, Software Systems, or Controls, Robotics & Autonomy. If a student prefers a less focused approach they can still pursue a general electrical engineering major or a general computer engineering major.

In addition to undergraduate degrees, the department also offers M.S., M.Eng., and Ph.D. programs in both EE and CPE. An accelerated undergraduate/graduate (UG/G) program is available for qualified undergraduates.

Electrical engineers (EEs) and computer engineers (CPEs) create important and exciting technologies, systems and applications that make the world a better place for all of us. EEs and CPEs are inventing new ways to generate, distribute and use electric power that are more efficient, more sustainable and friendlier to the environment. For example, wider use of solar energy relies on improved photovoltaic devices, power electronics for energy conversion, and power grids. Some of our most critical global infrastructures, including the Internet, mobile voice and data networks, and the electric power grid are designed by EEs and CPEs. And, EEs and CPEs design sensors and embedded systems to monitor intelligent buildings and transportation systems. Applying innovative technologies to biology and the healthcare industry, EEs and CPEs create techniques for medical imaging, micro-electromechanical systems for medical diagnostics, implantable devices for health monitoring and drug delivery, and information systems to improve healthcare delivery. To meet the challenge of cybersecurity, EEs and CPEs design hardware and software for cryptographic algorithms and develop methods to ensure private communications through the Internet and wireless devices. They design new devices and systems for high-performance computing and networking. They build satellites and instruments to improve communications and enhance our knowledge of space and the Earth. And, EEs and CPEs enhance our leisure time by creating new ways to listen to music, watch movies, play games, communicate with friends, and build social networks.

Students in the Bradley Department of Electrical and Computer Engineering learn from faculty who work at the cutting-edge of engineering research and bring the excitement of their discoveries to the classroom. Engineers want to make things that work. EE and CPE students get hands-on opportunities to build components and systems from the beginning of their studies. In the freshman year, students explore applications of electrical and computer engineering, such as medical imaging and cryptography. In the sophomore year, EE and CPE students use personal, portable equipment and components to build and explore simple digital and analog electronic systems, which become more complex each semester. Laboratories and team projects throughout the curriculum contribute to an enriching hands-on, minds-on learning experience. During their senior year, students participate in a team-based, industry-sponsored design project that spans two semesters in which they solve real-world engineering problems while learning project management and team-building skills.

Electrical engineering and computer engineering are dynamic and fast changing fields that drive innovation and solutions to global challenges. The ECE faculty has created a program of study that provides each graduate with a firm foundation in mathematics, physics, and engineering principles, and with broad experience in different areas of EE and CPE. The program enables our graduates to excel in their EE and CPE majors, while gaining the tools to adapt to the technical changes and career opportunities they will experience in the future. EE and CPE students develop effective communication and teamwork skills and gain knowledge of ethics, all of which are essential to professional success. EE and CPE graduates are prepared to pursue careers in industry and government, advanced graduate work in EE and CPE, and other advanced professional degrees.

ECE seeks to develop tomorrow's engineering and technical leaders and innovators. Students can enhance their undergraduate experience by participating in multidisciplinary team projects, cooperative education and internships, research experiences for undergraduates, study abroad programs, dual degree and minor programs in other fields, and mentoring programs. The Cooperative Education (co-op) and Internship Program is highly recommended, as is participation in professional societies, including the Institute of Electrical and Electronics Engineers (IEEE), Eta Kappa Nu (HKN), and the Association for Computing Machinery (ACM). ECE works with the Ted and Karyn Hume Center for National Security and Technology to develop future leaders for the US government. ECE offers many scholarships for academic excellence, leadership and service, as well as for participation in various special academic programs.

Accreditation

The Bachelor of Science in **Computer Engineering** (BSCPE) degree program is accredited by the Engineering Accreditation Commission of ABET (https://www.abet.org/), under the commission's General Criteria and Program Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs.

The Bachelor of Science in **Electrical Engineering** (BSEE) degree program is accredited by the Engineering Accreditation Commission

of ABET (https://www.abet.org/), under the commission's General Criteria and Program Criteria for Electrical, Computer, Communications, Telecommunication(s) and Similarly Named Engineering Programs.

Program Educational Objectives

The electrical and computer engineering programs integrate a strong and broad technical education with experiential learning and engineering professionalism training to provide our graduates the necessary knowledge and skills to solve complex 21st century problems. Within a few years of graduation, graduates from either of these programs will be:

- Advancing knowledge and making significant contributions to a variety of constituencies
- Seeking advanced degrees and life-long learning opportunities to maximize their contributions to society
- Emerging as entrepreneurs, researchers, or innovators in multi-disciplinary domains
- Contributing value to their employers and communities as conscientious and ethical professionals

Student Outcomes

Upon completion of the undergraduate program curriculum in Computer Engineering or Electrical Engineering, students will attain the following outcomes:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An 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. An ability to communicate effectively with a range of audiences.
4. An 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. An ability to function effectively on a team whose members together provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

- Applied Electromagnetics Major (https://catalog.vt.edu/undergraduate/college-engineering/electrical-computer-engineering/electrical-engineering-bs-applied-electromagnetics/)
- Chip-Scale Integration Major (https://catalog.vt.edu/undergraduate/college-engineering/electrical-computer-engineering/computer-engineering-bs-chip-scale-integration/)
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- Wireless Communications and Signal Processing Major (https://catalog.vt.edu/undergraduate/college-engineering/electrical-computer-engineering/electrical-engineering-bs-wireless-communications-signal-processing/)

Head: Rose Hu
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Alumni Distinguished Professor Emeritus: C. W. Bostian
Bradley Distinguished Professor Emeritus of Electromagnetics: G. S. Brown
Roanoke Electric Steel Professor in Engineering Emeritus: L. F. Lester

Thomas Phillips Professor Emeritus: W. L. Stutzman
American Electric Power Professor Emeritus: Chen-Ching Liu
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Virginia Microelectronics Consortium Professor: M. Agah
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Grant A. Dove Professor: Yue (Joseph) Wang
J. Byron Maupin Professor: W. A. Scales

W Martin Johnson Professorship: H. Dhillon

Rolls Royce Commonwealth Professorship: W. Saad

Elizabeth and James E. Turner Jr. '56 Faculty Fellowship: Q. Li
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Bradley Professor of Cybersecurity: L. DaSilva
Bradley Senior Faculty Fellow: S. M. Bailey, L. Liu, and B. Ravindran

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Associate Professors: W. T. Baumann, T. Chantem, C. C. DiMarino, D. Dong, S. W. Ellingson, R. Gerdes, M. Hudait, M. Limes, M. Manteghi, J. Paul, J. Walling, R. Williams, C. L. Wyatt, H. Zeng, Y. Zhang, W Zhou, and Y. Zhu
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Collegiate Assistant Professors: A. H. Ball, A. M. Boker, K. Giles, S. Shin, M. Lanzerotti, and R. Raghunathan
Adjunct Professors of Practice: D. M. Sable, E. Meadows, and K. R. Schulz
Advanced Instructors: J. Thweatt
Instructors: T. Milburn, A. Sarker, and S. Yu

Undergraduate Course Descriptions (ECE)

ECE 1004 - Introduction to ECE Concepts (3 credits)
Introduction to topics that span the field of electrical and computer engineering (ECE). Content is presented through the lens of application with accompanying hands-on exercises. Basics of circuits, op-amps, computer logic, and computer programming are covered. Engineering ethics and its societal challenges are considered.
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2024 - Circuits and Devices (3 credits)
Analysis and design of passive and active circuits under Direct Current (DC), Alternating Current (AC), and switched excitation. Linear circuit analysis techniques for various circuit topologies. Expressing the transient response of first- and second-order linear circuits using time-domain methods. Calculating the AC steady-state response of linear circuits using phasors. Characterizing the frequency response of linear circuits. Determining operating point and small signal response of non-linear circuits containing diodes and bipolar transistors.
Prerequisite(s): ECE 1004 and (MATH 2114 or MATH 2114H or MATH 2405H)
Corequisite(s): MATH 2214, PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2054 - Applied Electrical Theory (3 credits)
For students in the Mechanical Engineering program or by permission of the ECE Department. Fundamentals of electric circuits; circuit laws and network theorems, operational amplifiers, energy storage elements, response of first and second order systems, AC steady state analysis. Construction, analysis, and characterization of circuits with student-owned Lab-in-a-Box system.
Prerequisite(s): PHYS 2306
Corequisite(s): MATH 2214
Instructional Contact Hours: (2 Lec, 2 Lab, 3 Crd)

ECE 2164 - Exploration of the Space Environment (3 credits)
This introductory course covers a broad range of scientific, engineering, and societal aspects associated with the exploration and technological exploitation of space. Topics covered include: science of the space environment; space weather hazards and societal impacts; orbital mechanics and rocket propulsion; spacecraft subsystems; applications of space-based technologies.
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 2664

ECE 2214 - Physical Electronics (3 credits)
Fundamentals of electrostatics, magnetostatics, and transmission lines, including impedance matching networks. Introduction to electromagnetic (EM) waves, with calculation of phase velocity using Maxwell's equations. Examination of semiconductor physics, including carrier concentrations, drift, and diffusion currents. Analysis of PN diode circuits and metal-oxide-semiconductor field-effect transistors (MOSFET) amplifiers. Exploration of Faraday's Law in transformer and generator performance. Design of MOSFET biasing and amplifier circuits. Introduction to CMOS devices and digital inverters. Emphasis on ethical and professional practices in electronic circuit design.
Prerequisite(s): ECE 2024
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2274 - Electronic Networks Laboratory I (1 credit)
Principles of operation of electrical and electronic test equipment and applications to measurement of circuit parameters. Transient and steady state response of RLC networks. Applications of laws and theories of circuits. Design, prototyping, and testing of electronic devices and circuits. Must have C- or better in prerequisite.
Prerequisite(s): ECE 2074
Corequisite(s): ECE 2204
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 2514 - Computational Engineering (3 credits)
Software development processes for electrical and computer engineering applications. Modeling, simulation, data analysis, and visualization. Computing abstractions and the use of application programming interfaces. Software design and implementation using a procedural, class-based language. Integrated code development and testing. Team-based development of autonomous system applications reinforcing course topics.
Prerequisite(s): ECE 1004
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2544 - Fundamentals of Digital Systems (3 credits)
Design and analysis of digital systems. Information representations and computer arithmetic. Switch and gate design within digital logic. Combinational logic analysis and synthesis, Hardware Description Languages (HDL), and hierarchical design. Finite-state machines, synchronous sequential logic analysis and design. Hardware specification and documentation. Register transfer level architectures, computer organization, memories, and digital interfacing. Instruction set architecture and assembly language programming. Emphasis on the relationship between software and hardware.
Prerequisite(s): ECE 1004
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2564 - Embedded Systems (3 credits)
Use of microcontroller-based embedded systems as a tool to address digital control and sensing in engineering applications. Modern methodologies for programming microcontrollers including programming under real-time and resource design constraints. Finite-state machine modeling and software implementation. Event-driven programming including polling-based and interrupt-driven input/output. Integration of sensors and actuators, use of standard digital and analog interfaces, and use of hardware peripherals in microcontroller architectures. Design of hardware abstraction layers and software architectures for embedded systems. Integration of hardware peripherals into real-time, software applications. Software toolchains for embedded systems, use of debugger and development and testing methodologies. Professional project management and version control.
Prerequisite(s): ECE 2514 and ECE 2544
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2714 - Signals and Systems (3 credits)
Mathematical methods for the analysis and design of continuous and discrete linear, time-invariant systems. Representation of signals using time-domain and frequency-domain methods and the application of Fourier transforms to linear system design and analysis. Descriptions of systems as signal transformations using block diagrams, differential equations, difference equations, convolution, and transfer functions. Applications to signal filtering, measurement, and control of the physical devices. Formal project documentation adhering to professional practices.
Prerequisite(s): ECE 2024 and (MATH 2214 or MATH 2214H or MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 2804 - Integrated Design Project (2 credits)
Review of circuit design and measurement techniques. Design, implementation, testing, and validation of a hardware and software solution to an open-ended engineering problem integrating both analog and digital components. Technical documentation and oral presentation of the design process and solution. Introduction to topics in engineering professionalism, career development, and industrial perspectives.
Prerequisite(s): ECE 2024 and ECE 2514 and ECE 2544
Corequisite(s): ECE 2214 and (ECE 2564 or ECE 2714)
Instructional Contact Hours: (1 Lec, 3 Lab, 2 Crd)

ECE 2964 - Field Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 2974 - Independent Study (1-19 credits)
A minimum GPA of 2.0 in all ECE courses is required for enrollment.
Instructional Contact Hours: Variable credit course

ECE 2984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 2994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 3004 - AC Circuit Analysis (3 credits)
Application of the basic laws and techniques of circuit analysis to AC circuits. Complex numbers and algebra with an emphasis on phasor representation of circuits. Calculation of the frequency response of circuits with R, L, and C components, independent sources, controlled sources, and operational amplifiers. Analysis of AC steady-state circuits and determination of average power. Magnetically coupled circuits. Laplace and Fourier transforms. Representation of circuits by two-port models. C- or better in prerequisites.
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3054 - Electrical Theory (3 credits)
For students in curricula other than ECE or ME. Fundamentals of electric circuits and electronic devices. Fundamentals of electric circuits: circuit laws and network theorems, operational amplifiers, energy storage elements, response of first (Resistive-Inductive RL, and Resistive Capacitive RC) and second order (Resistive-Inductive-Capacitive RLC) systems, Alternating Current (AC) steady state analysis. Basic electronic devices: Diodes and Transistors.
Prerequisite(s): PHYS 2306
Corequisite(s): MATH 2214
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3074 - AC Circuit Analysis Laboratory (1 credit)
Construction, analysis, and characterization of circuits with student-owned Lab-in-a-Box system. Experiments include: sinusoids and phasors including impedance, admittance, and Kirchhoffs laws; sinusoidal steady- state including node and mesh analysis, Thevenin and Norton equivalent, and op amps; ac power analysis including instantaneous and average power, power factor, and complex power; magnetically coupled circuits including mutual inductance, energy in a coupled circuit, and transformers; frequency response including transfer functions, Bode plots, resonance, and passive and active filters; and two-port circuits. A C- or better is required for all prerequisites.
Prerequisite(s): ECE 2804
Corequisite(s): ECE 3004
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 3104 - Introduction to Space Systems and Technologies (3 credits)
Introduction to technologies and computational tools used in space-based applications, including techniques for exploring the planets and the near-Earth geospace environment. Overview of orbits, spacecraft, control of spacecraft, electromechanical system requirements for space-based applications, and space environment interactions with spacecraft systems. Understanding the space environment and the engineering approaches required to operate it. A C- or better is required in prerequisites.
Prerequisite(s): ECE 3105
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3105 - Electromagnetic Fields (3 credits)
Maxwells equations and their application to engineering problems. ECE 3105: transmission lines, introductory electrostatics, introductory magnetostatics, Faradays Law, properties of uniform plane waves. ECE 3106: electrostatics and magnetostatics, Maxwells Equations, wave propagation in uniform media, the reflection and transmission of plane waves, guided waves, radiation. A C- or better is required in the prerequisites.
Prerequisite(s): ECE 2214 and (MATH 2204 or MATH 2204H or MATH 2406H) and PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3106 - Electromagnetic Fields (3 credits)
Maxwells equations and their application to engineering problems. ECE 3105: transmission lines, introductory electrostatics, introductory magnetostatics, Faradays Law, properties of uniform plane waves. ECE 3106: electrostatics and magnetostatics, Maxwells Equations, wave propagation in uniform media, the reflection and transmission of plane waves, guided waves, radiation. A C- or better is required in the prerequisites.
Prerequisite(s): ECE 3105
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3134 - Introduction to Optoelectronics (3 credits)
Fundamental principles of optoelectronics. The concept of photons, spontaneous emission, and simulated emission. Rate equation analysis of light emitting diodes and lasers. Operation principles and device characteristics of photodetectors and solar cells. Advanced topics such as quantum well and emerging materials.
Prerequisite(s): ECE 2214
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3154 - Space Systems - Design and Validation (2 credits)
Introduction to systems and techniques used in electrical engineering design for space-based applications. Students design, fabricate, and test an electronic system following accepted NASA and industry standards, including functional bench-top tests, thermal testing, vibration testing, and long-duration operational testing. Periodic formal reports will document design approaches and test results.
Prerequisite(s): ECE 3105
Corequisite(s): ECE 3104
Instructional Contact Hours: (1 Lec, 3 Lab, 2 Crd)

ECE 3174 - Optoelectronics Laboratory (1 credit)
Characterization of optoelectronic devices such as light emitting diodes, semiconductor lasers, and photodetectors. Characterization and analysis of optical interference, wave propogation in optical fibers, and optical diffraction. Construction of simple optical imaging systems using lenses and bulk optics.
Prerequisite(s): ECE 2804
Corequisite(s): ECE 3134
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 3204 - Analog Electronics (3 credits)
Small signal modeling of transistors. Basic architecture and functionality of linear amplifiers including transistor biasing circuits, current sources, differential amplifier, common emitter amplifier, common source amplifier, emitter follower, source follower, common base amplifier, and common gate amplifier. Frequency response of single stage and multistage amplifiers.
Prerequisite(s): ECE 2214 and ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3214 - Semiconductor Device Fundamentals (3 credits)
Fundamental semiconductor device physics associated with intrinsic and doped semiconductor materials, drift-diffusion of charge carriers, and devices with an in-depth coverage of p-n and Schottky diodes, bipolar junction transistors, and metal-oxide semiconductor and junction field effect transistors.
Prerequisite(s): ECE 2214 or MSE 3204
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3254 - Industrial Electronics (3 credits)
Fundamentals of electronics, including basic device principles. Include digital, operational amplifier, and analog analysis for industrial applications and magnetic circuits. For students in the Mechanical Engineering program or by permission of the ECE Department.
Prerequisite(s): ECE 2054
Instructional Contact Hours: (3 Lec, 0 Lab, 3 Crd)

ECE 3274 - Electronic Circuits Laboratory II (1 credit)
Design, build, and test amplifiers and other electronic circuits to meet specifications. Bipolar and field-effect transistors, diodes, integrated circuits such as operational amplifiers, and passive components are used. Gain, bandwidth, input and output impedance, positive and negative feedback, and circuit stability are implemented in the designs. Digital oscilloscopes, ammeters, voltmeters, function generators, and power supplies are used. A grade of C- or better is required in all pre-requisite courses.
Prerequisite(s): ECE 3074
Corequisite(s): ECE 3204
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 3304 - Introduction to Power Systems (3 credits)
Basic concepts of AC systems, single-phase and three-phase networks, electric power generation, transformers, transmission lines, electric machinery and the use of power. Pre-requisite 3004 with C- or better.
Prerequisite(s): ECE 3004
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3354 - Electric Power Engineering Laboratory (1 credit)
Laboratory experiments based on principles of electric power engineering.
Corequisite(s): ECE 3304
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 3504 - Principles of Computer Architecture (3 credits)
Instruction formats and construction. Addressing modes. Memory hierarchy (cache, main memory and secondary memory) operation and performance. Simple pipelines. Basic performance analysis. Simple Operating System (OS) functions, particularly as they relate to hardware. Virtual memory. Computer Input/Output (I/O) concepts, including interrupt and Direct Memory Access (DMA) mechanisms. Intercomputer communication concepts. Processor design.
Prerequisite(s): ECE 2544
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3514 - Data Structures & Algorithms (3 credits)
Introduction of fundamental data structures, algorithms, and abstract data types. Data structures, arrays, linked lists, stacks, queues, and trees. Algorithms for manipulation, sorting, searching. Tree traversals. Implementation of data structures and algorithms in C++ using good design practices.
Prerequisite(s): ECE 2514
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3524 - Introduction to Unix for ECE (2 credits)
Fundamental concepts of operating systems, emphasizing a hands-on introduction to Unix. User interfaces, Unix shell commands, the Unix file system, task management, common system utilities, the Unix programming environment. Students gain experience with system installation and administration.
Prerequisite(s): ECE 2804
Instructional Contact Hours: (2 Lec, 2 Crd)

ECE 3544 - Digital Design I (4 credits)
Design techniques for combinational and sequential logic. Design of digital circuits using standard integrated circuit chips and programmable logic devices. Computer simulation will be used to validate designs. Prototypes will be constructed to demonstrate design functionality.
Prerequisite(s): ECE 2544
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ECE 3564 - Introduction to Computer Networking (3 credits)
Introduction to computer networking featuring the Internet. Internet architecture and layering. Application layer service models and protocols. Transport layer protocols and congestion control. Internet addressing, routing algorithms and protocols. Multiple access and link layer addressing, wireless local area networks (LANs) and cellular networks.
Prerequisite(s): ECE 2544 and ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3574 - Applied Software Design (3 credits)
An introduction to applied software design methods for use in the writing of efficient, reusable, and modular C++ programs. Introduces the use of the following: classes, inheritance, and polymorphism; design patterns; high-level programming techniques using libraries, generics, and containers; widgets, models, and views; software frameworks for embedded systems; and advanced techniques ranging from multi-threading to reflective programming.
Prerequisite(s): ECE 3514
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3604 - Introduction to RF and Microwave Engineering (3 credits)
Introduction to circuits, devices, and systems for radio frequency (RF) and microwave applications. Fundamentals of antennas, propagation, small signal and power amplifiers, frequency conversion, and frequency synthesis. Tools and concepts including s-parameters, design impedance matching, dynamic range, noise figure, and link budget.
Prerequisite(s): ECE 3105
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3614 - Introduction to Communication Systems (3 credits)
Analysis and design of communication systems with an emphasis on digital communications based on time and frequency domain analysis. Fourier transform techniques, linear systems, and filtering are reviewed. Power and energy spectral density of communication signals. Sampling and quantization of analog signals. Baseband and binary bandpass digital modulation including line coding, pulse shaping, and both pulse and carrier modulation techniques. Wireless communication system concepts including link budgets and multiple access. Transmitter and receiver design concepts. Signal-to-noise ratio, bit error rate, and their relationship. Analog techniques such as Amplitude Modulation (AM) and Frequency Modulation (FM) radio will be reviewed for conceptual and comparative purposes.
Prerequisite(s): ECE 2714 and STAT 4714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3704 - Continuous and Discrete System Theory (3 credits)
Continuous- and discrete-time system theory. Block diagrams, feedback, and stability theory. Continuous-time stability, differential equations, Laplace-transforms, transfer functions. Discrete-time stability, difference equations, Z-transforms. Transfer functions and frequency response. Sampling of continuous systems and an introduction to control and filter design. Hands-on projects to illustrate and integrate the various continuous- and discrete-time concepts and tools.
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3714 - Introduction to Control Systems (3 credits)
Introduction to the design of feedback compensation to improve the transient and steady-state performance of systems. Emphasis is on modeling, analysis and analog compensator design for single-input single-output systems. Modeling techniques, root locus analysis and design, the Nyquist criterion, and frequency domain compensation.
Prerequisite(s): ECE 3704
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 3964 - Field Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 3974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 3984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 4104 - Microwave and RF Engineering (4 credits)
Passive and active Radio Frequency and microwave components and circuits for wireless communications; transmission-line theory; planar transmission-lines and waveguides; S-parameters; resonators; power dividers and couplers; microwave filters; sources, detectors, and active devices; modern RF & microwave CAD; measurement techniques. C- or better in prerequisites.
Prerequisite(s): ECE 3106 and ECE 3204
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ECE 4110 - Quantum Engineering Laboratory (3 credits)
Introduction to fundamental science concepts and laboratory implementation of quantum engineering applications. Science concepts include wave-particle duality, quantum erasure, quantum entanglement and engineering applications include quantum communication, Bennett-Brassard 1984 (BB84) and Ekert 1991 (Ekert91) Quantum Key Distribution (QKD) protocols for quantum cryptography, quantum sensing, quantum interferometry, and quantum state tomography.
Prerequisite(s): MATH 2114 and PHYS 2306
Instructional Contact Hours: (1 Lec, 6 Lab, 3 Crd)

ECE 4114 - Antennas (3 credits)
Antenna fundamentals, analysis and design principles, and a survey of antenna types including: arrays, wire antennas, broadband antennas, and aperture antennas.
Prerequisite(s): ECE 3106
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4120 - Fundamentals of Quantum Engineering (3 credits)
Introduction to fundamental concepts and engineering principles of quantum physics, quantum computing, quantum communication, and quantum sensing. The quantum physics section includes quantum states, superposition, entanglement, quantum measurements. The quantum computing section includes quantum bits, gates, circuits, algorithms, and quantum error correction. The quantum communication section includes toy models for quantum key distribution and quantum teleportation. The quantum sensing section includes solid-state quantum defect sensors and single photon detection. Software quantum simulators will also be introduced, providing hands-on experience with quantum gates, measurements, and algorithms. Pre: Junior Standing
Prerequisite(s): MATH 2114 and MATH 2204
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4124 - Radio Wave Propagation (3 credits)
Behavior of radiated electromagnetic waves in terrestrial, atmosphere, space, and urban environments; path, frequency and antenna selection for practical communication systems; propagation prediction.
Prerequisite(s): ECE 3106
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4134 - Photonics (3 credits)
Fundamental concepts in photonics technology. Basic principles of optical fibers and components such as Bragg gratings, amplifiers, couplers and modulators used in optical communications and sensing. Propagation, dispersion, bandwidth and nonlinear properties of optical signals in optical waveguides and fibers.
Prerequisite(s): ECE 3105
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4144 - Optical Systems (3 credits)
Fundamental concepts in optical information processing. Ray optics. Optical diffraction. Basic principles and applications of optical imaging using wave optics. Properties of Gaussian Beam. Introduction to Fourier optics, optical spatial filtering, 3D image reconstruction and holography.
Prerequisite(s): ECE 3106
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4154 - Space Weather: The Solar Wind and Magnetosphere (3 credits)
Solar-terrestrial interactions and space weather: the sun, solar wind, and interplanetary magnetic field; space plasma physics and magnetohydrodynamics; Earths magnetosphere and ionosphere; geomagnetic storms and auroral substorms; societal impacts of space weather; planetary magnetospheres; space science instrumentation.
Prerequisite(s): ECE 3105 or AOE 3014
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4654

ECE 4164 - Introduction to Global Positioning System (GPS) Theory and Design (4 credits)
Fundamental theory and applications of radio navigation with the Global Positioning System GPS. Satellite orbit theory, GPS signal structure and theory, point positioning with pseudoranges and carrier phases, selective availability, dilution of precision, differential GPS, atmospheric effects on GPS signals.
Prerequisite(s): ECE 3105 or AOE 4134
Instructional Contact Hours: (3 Lec, 1 Lab, 4 Crd)
Course Crosslist: AOE 4464

ECE 4174 - Upper Atmosphere/Ionosphere Space Weather (3 credits)
Interaction of Earth's upper atmosphere and space environment with spacecraft: processes that affect atmospheric density relevant to spacecraft orbit decay; basic composition and structure; radiation and radiative transfer; atmospheric energy balance; atmospheric chemistry and ion production/loss mechanisms; fundamental concepts of Solar-terrestrial physics including ionospheric Chapman theory; atmospheric energy/mass transport; ionospheric electrodynamics; ionospheric storms; planetary atmospheres/ionospheres; instrumentation.
Prerequisite(s): AOE 3014 or ECE 3105
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4674

ECE 4184 - Applied Quantum Mechanics for Engineers (3 credits)
Review of classical mechanics, the simple harmonic oscillator. Schrodinger equation, barrier tunneling, resonant tunneling, and quantum wells. Mathematical foundation of quantum mechanics, Dirac notation and representations, observables, eigenstates and diagonalization. Quantum postulates and its application to two-level systems, harmonic oscillators, creation and annihilation operators. Time evolution of a Hamiltonian. Dynamics of spin and two-level atoms. No cloning theorem and the concept of entanglement.
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4194 - Engineering Principles of Remote Sensing (3 credits)
Physical principles involved in remote sensing of Earths environment and their implementation in engineering systems: fundamentals of electromagnetic wave propagation, scattering by matter, effects of propagation media, passive and active systems, remote sensing platforms, data processing, systems integration, and introductory concepts important for the design and analysis of remote sensing engineering systems.
Prerequisite(s): ECE 3106
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4205 - Electronic Circuit Design (3 credits)
Stability and response of feedback amplifier, wideband amplifiers, operational amplifier characteristics, waveform generators and wave shaping, nonlinear circuit applications, signal generators, and photolithography. Design of analog electronic circuits, circuit simulation, response characterization, and printed circuit construction. C- or better in prerequisites.
Prerequisite(s): ECE 2214
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4220 - Analog Integrated Circuit Design (3 credits)
Integrated circuit design in silicon bipolar, MOS (Metal-Oxide-Semiconductor), and BiCMOS (Bipolar Complementary Metal-Oxide-Semiconductor) technologies for communications, sensor, instrumentation, data conversion, and power management applications. Models for active devices in bipolar and MOS technologies; transistor-level amplifiers and output stages (amplifier classifications); transistor-level current mirrors and voltage reference generators, transistor-level operational amplifiers; transistor-level feedback circuits; noise and linearity; layout and simulation of analog integrated circuits with modern VLSI CAD (Very Large Scale Integration- Computer Aided Design) software.
Prerequisite(s): ECE 3204
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4224 - Power Electronics (3 credits)
Switching power converter operation and design; modeling of power converters; power components including power semiconductor devices, inductors, and transformers; control of power converters; select power converter topology for applications such as renewable energy, electric transportation, and telecommunications.
Prerequisite(s): ECE 3204 and ECE 3304
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4234 - Semiconductor Processing (3 credits)
Manufacturing practices used in silicon integrated circuit fabrication and the underlying scientific basis for these process technologies. Physical models are developed to explain basic fabrication steps, such as substrate growth, thermal oxidation, dopant diffusion, ion implantation, thin film deposition, etching, and lithography. The overall CMOS integrated circuit process flow is described within the context of these physical models.
Prerequisite(s): ECE 2214
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: MSE 4234

ECE 4244 - Intermediate Semiconductor Processing Laboratory (3 credits)
Design, layout, fabricate, and characterize microelectronic devices. Analyze test results to verify performance to the predetermined specifications. Required oral and written reports. A C- or higher is required in all pre-requisite courses.
Prerequisite(s): ECE 4234 or MSE 4234
Instructional Contact Hours: (1 Lec, 6 Lab, 3 Crd)

ECE 4254 - Principles of Electronics Packaging (3 credits)
Electrical and thermal design of electronics packaging using finite element analysis software. Materials and process selection guidelines for the fabrication of single- and multi-chip electronics packages. Methods for characterization and testing of electronics packages. Failure mechanisms and design for reliability. Hands-on project experience on electronics packaging.
Prerequisite(s): ECE 2214 or ECE 2054 or ECE 3054
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4284 - Power Electronics Laboratory (1 credit)
Design and testing of electronic power processing systems for commercial and aerospace applications.
Corequisite(s): ECE 4224
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 4314 - Electric Energy Distribution Systems (3 credits)
Fundamentals of electric power distribution systems. Load characteristics. Modeling of distribution system components (line segments, voltage regulators, and transformers). Distribution flow analysis. Capacitor placement. Symmetrical components and calculation of fault currents. Protection of distribution feeders. Automation/control technologies to enhance reliability, resilience, and security.
Prerequisite(s): ECE 3004
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4324 - Microgrids (3 credits)
Microgrid: definitions, components, and modes of operation; steady-state analysis and power quality; control modes and hierarchy; renewable resources and their inverter grid-forming and grid-following modes; protection strategies; emerging topics e.g., DC microgrids and datacenters; cybersecurity.
Prerequisite(s): ECE 3004
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4334 - Power System Analysis and Control (3 credits)
Development of methods for power analysis and control. An analysis and design of systems for steady state, transient, and dynamic conditions. Digital solutions emphasized.
Prerequisite(s): ECE 3304
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4354 - Power System Protection (3 credits)
Protection of power apparatus and systems. Fuses. Voltage and current transducers. Relays. Coordination of relays. Pilot channels. Grounding practices. Surge phenomena. Insulation coordination.
Prerequisite(s): ECE 4334
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4364 - Alternate Energy for Climate Sustainability (3 credits)
Electric energy from alternative energy sources including solar, wind, hydro, biomass, geothermal, ocean, and advanced nuclear reactors. Characteristics of direct conversion, electromechanical conversion, and storage devices used in alternative energy systems. Power system issues associated with integration of small-scale energy sources into the electricity grid. Carbon dioxide emission reduction from energy transition.
Prerequisite(s): STAT 3704 or STAT 4604 or STAT 4705 or STAT 4714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4414 - Linux Kernel Programming (3 credits)
Design and internal organization of the Linux operating system kernel. Kernel subsystems, boot process, memory management, process and thread model, scheduling, interrupt and exception handling, virtual file system and the concrete file system, block I/O and I/O scheduler, network stack, and device drivers. Modification of existing kernel code. Design, implementation, test and evaluation of new kernel modules. Kernel and full software stack debugging techniques, and virtualization as an aid for operating system development and debug. Software engineering techniques to analyze, modify and run a large, complex open-source code base.
Prerequisite(s): ECE 3574 or CS 3114
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CS 4224

ECE 4424 - Machine Learning (3 credits)
Algorithms and principles involved in machine learning; focus on perception problems arising in computer vision, natural language processing and robotics; fundamentals of representing uncertainty, learning from data, supervised learning, ensemble methods, unsupervised learning, structured models, learning theory and reinforcement learning; design and analysis of machine perception systems; design and implementation of a technical project applied to real-world datasets (images, text, robotics). A grade of C- or better in prerequisites.
Prerequisite(s): (ECE 3514 or CS 2114) and (STAT 3704 or STAT 4105 or STAT 4604 or STAT 4705 or STAT 4714 or CMDA 2006)
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CS 4824

ECE 4444 - Technological Singularity (3 credits)
True artificial machine intelligence. Societal impact. Historical perspectives. Technological barriers to whole brain emulation. Engineering of superintelligence. Role of consciousness. Cross disciplinary course for students with advanced technical backgrounds, e.g., seniors in engineering, math, physics, biology, or other similar disciplines.
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4454 - Multimedia Signal Processing (3 credits)
Signal processing techniques in multimedia systems: concept and principle of multimedia systems; speech analysis and recognition; audio/image/video compression; scene video analysis & understanding; multimedia applications such as human computer interaction, multimedia communication and multimedia security.
Prerequisite(s): ECE 2704 or (ECE 2714 and ECE 2804)
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4504 - Computer Organization (3 credits)
Overview of the structure, elements and analysis of modern enterprise computers. Performance evaluation of commercial computing. Past and emerging technology trends. Impact of parallelism at multiple levels of computer architecture. Memory and storage. Fundamental computer system descriptions, Amdahls Law, Flynns Taxonomy. A grade of C or better required in prerequisites.
Prerequisite(s): ECE 3504 or CS 3214
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CS 4504

ECE 4514 - Digital Design II (4 credits)
Advanced digital design techniques for developing complex digital circuits. Emphasis on system-level concepts and high-level design representations while meeting design constraints such as performance, power, and area. Methods presented that are appropriate for use with automated synthesis systems. Commercial hardware description language simulation and synthesis tools used for designing a series of increasingly complex digital systems, and implementing those systems using Field Programmable Gate Arrays (FPGAs).
Prerequisite(s): ECE 3544
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ECE 4520 - Digital and Mixed-Signal System Testing and Testable Design (3 credits)
Various topics on testing and testable design for digital and mixed-signal systems are studied: fault modeling, logic and fault simulation, fault modeling, automatic test pattern generation, deterministic ATPG, simulation-based ATPG, delay fault testing, design for testability, built-in-self-test and fault diagnosis.
Prerequisite(s): ECE 3514 and (ECE 3504 or ECE 3544)
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4524 - Artificial Intelligence and Engineering Applications (4 credits)
Problem solving methods; problem spaces; search techniques; knowledge representation; programming languages for AI; games; predicate logic; knowledge-based systems; machine learning; planning techniques; reactive systems; artificial neural networks; natural language understanding; computer vision; robotics.
Prerequisite(s): ECE 3514 and STAT 4714
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ECE 4525 - Video Game Design and Engineering (3 credits)
4525: Fundamental concepts in the development and engineering of modern 2-D and 3-D real-time interactive computer video games. Game design and engineering principles, game architecture, game mechanics and interaction, computer graphics, strategy, artificial intelligence (AI), optimization, play testing and fuzzy logic are included. 4526: Advanced concepts in the development and engineering of modern 2-D and 3-D real-time interactive computer video systems. Topics include non-player character (NPC) behavior learning, search and planning, player modeling, procedural content generation, AI-assisted game design.
Prerequisite(s): ECE 3574
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4526 - Video Game Design and Engineering (3 credits)
Prerequisite(s): ECE 4525
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4530 - Hardware-Software Codesign (3 credits)
An introduction to the design of mixed hardware- software systems, focusing on common underlying modeling concepts, the design of hardware-software interfaces, and the trade-offs between hardware and software components. Students will use simulation tools to conduct experiments with mixed hardware- software systems in the area of embedded systems.
Prerequisite(s): (ECE 2534 or ECE 2564) and ECE 3544
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4534 - Embedded System Design (4 credits)
Team-based major design experience. Design and implement embedded computer systems that incorporate appropriate engineering standards to solve complex problems that include multiple realistic constraints. Writing design documents and making oral presentations as part of the design process. C- or better required in prerequisites.
Prerequisite(s): (ECE 2014 and ECE 2534 and ECE 3574) or (ECE 2564 and ECE 2804 and ECE 3574)
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ECE 4540 - VLSI Circuit Design (3 credits)
Introduction to the design and layout of Very Large Scale Integrated Circuits (VLSI). Emphasis is placed on digital CMOS circuits. Static and dynamic properties of MOSFET devices, along with integrated circuit fabrication are examined. Computer-aided design tools are used to produce working integrated circuit designs.
Prerequisite(s): ECE 2214 and ECE 2544
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4550 - Real-Time Systems (3 credits)
Theory, algorithmic and protocol concepts, mechanisms, and implementations of real-time computer systems. Introduction to real-time systems, real-time scheduling, real-time synchronization, real-time operating system kernels, and real-time resource management algorithms (e.g., scheduling, synchronization), their implementations in production operating system kernels, experimental studies of those implementations, and real-time application development.
Prerequisite(s): ECE 3574 or CS 3214
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4554 - Introduction to Computer Vision (3 credits)
Techniques for automated analysis of images and videos. Image formation, detecting features in images, segmenting or grouping image regions and image features, multiple view geometry, object instance and category recognition in images and video processing.
Prerequisite(s): ECE 3574 and (STAT 4705 or STAT 4714)
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4560 - Computer and Network Security Fundamentals (3 credits)
This course introduces fundamental security principles and real-world applications of Internet and computer security. Topics covered in the course include legal and privacy issues, risk analysis, attack and intrusion detection concepts, system log analysis, intrusion detection and packet filtering techniques, computer security models, computer forensics, and distributed denial-of-service (DDoS) attacks. Must have C- or better in ECE 4564 or CS 3214.
Prerequisite(s): ECE 3564 or CS 3214
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4564 - Network Application Design (3 credits)
Application program interface and network transport services including User Datagram Protocol and Transmission Control Protocol from the Internet Protocol suite. Client-server organization and design of synchronous, asynchronous, and multithreaded client and server applications. Design, implementation, and testing techniques to improve robustness and performance. Partially duplicates CS 4254 and credit will not be allowed for both.
Prerequisite(s): ECE 3564 and ECE 3514
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4570 - Wireless Networks and Mobile Systems (3 credits)
Multidisciplinary, project-oriented design course that considers aspects of wireless and mobile systems including wireless networks and link protocols, mobile networking including support for the Internet Protocol suite, mobile middleware, and mobile applications. Students complete multiple experiments and design projects.
Prerequisite(s): ECE 4564
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CS 4570

ECE 4574 - Large-Scale Software Development for Engineering Systems (3 credits)
Large-scale software implementations of the hierarchy of engineering analysis, design, and decision evaluation. Computer-aided engineering programs with state-of-the-art computer tools and methods. Operator overloading, dynamic polymorphism, graphical user interfaces, generic programming, dynamic link libraries, and multiple threads.
Prerequisite(s): ECE 3574
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4580 - Digital Image Processing (3 credits)
This course provides an introduction to basic concepts, methodologies and algorithms of digital image processing focusing on the two major problems concerned with digital images: (1) image analysis and object restoration for easier interpretation of images, and (2) image analysis and object recognition. Some advanced image processing techniques (e.g., wavelet and multiresolution processing) will also be studied in this course. The primary goal of this course is to lay a solid foundation for students to study advanced image analysis topics such as computer vision systems, biomedical image analysis, and multimedia processing & retrieval.
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4584 - Robotics Laboratory (1 credit)
Develop, compile, and test algorithms for serial and mobile robots. Robot forward and inverse kinematics, task planning, velocity kinematics, force rendering, control, haptics, mapping and localization, computer vision and path planning.
Corequisite(s): ME 4524 or ECE 4704
Instructional Contact Hours: (3 Lab, 1 Crd)
Course Crosslist: ME 4584

ECE 4605 - Radio Engineering (3 credits)
Wireless application circuit design for gain and filter control at radio frequencies to interface the baseband processing systems and the antennas of communication systems. 4605: Design of radio transmitter and receiver circuits using scattering-parameter methods. Circuits include oscillators, radio frequency amplifiers and matching networks, mixers and detectors. 4606: Design of amplitude, frequency, and pulse-modulated communication systems, including modulators, detectors, and the effects of noise. Design basics and guidelines for phase-locked loops and several power amplifier configurations.
Prerequisite(s): ECE 3105 and ECE 3204 and ECE 3614
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4606 - Radio Engineering (3 credits)
Wireless application circuit design for gain and filter control at radio frequencies to interface the baseband processing systems and the antennas of communication systems. 4605: Design of radio transmitter and receiver circuits using scattering-parameter methods. Circuits include oscillators, radio frequency amplifiers and matching networks, mixers and detectors. 4606: Design of amplitude, frequency, and pulse-modulated communication systems, including modulators, detectors, and the effects of noise. Design basics and guidelines for phase-locked loops and several power amplifier configurations.
Prerequisite(s): ECE 4605
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4624 - Digital Signal Processing And Filter Design (3 credits)
Analysis, design, and realization of digital filters. Discrete Fourier Transform algorithms, digital filter design procedures, coefficient quantization. Pre: C or better in 3704
Prerequisite(s): ECE 3704
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4634 - Digital Communications (3 credits)
System and signal level analysis and design for digital communications systems. Review of analog-to-digital conversion and digital baseband communications. Detailed analysis of digital carrier modulation formats including assessment of signal-to-noise ratio, bit error rate, and power and bandwidth efficiency for amplitude-shift keying (ASK), phase-shift keying (PSK), frequency-shift keying (FSK), and Quadrature-Amplitude Modulation (QAM). Matched filter receivers and receiver design, link budgets, and multiple access. Additive-white-noise Gaussian channels. A detailed discussion of random variables will be included to supplement prerequisite material. A C- or better is required in prerequisites.
Prerequisite(s): ECE 3614
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4644 - Satellite Communications (3 credits)
Theory and practice of satellite communications. Orbits and launchers, spacecraft, link budgets, modulation, coding, multiple access techniques, propagation effects, and earth terminals.
Prerequisite(s): ECE 3614
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4664 - Analog and Digital Communications Laboratory (1 credit)
Laboratory experiments which deal with the design and measurement of analog and digital communication systems. Concepts include SNR, Modulation Index, PCM, and spread spectrum.
Prerequisite(s): ECE 3614
Corequisite(s): ECE 4634
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 4675 - Radio Engineering Laboratory (1 credit)
Laboratory techniques for radio frequencies including the design of amplifiers, oscillators, and a single-side-band receiver. Associated measurements will be used.
Prerequisite(s): ECE 3106 and ECE 3204
Corequisite(s): ECE 4605
Instructional Contact Hours: (3 Lab, 1 Crd)

ECE 4684 - Network Science (3 credits)
Introduction to modern-day networked technologies such as wireless, social, and economic networks. Analysis of networked technologies using analytical and engineering techniques such as optimization, game/auction theory, graph analysis, and learning as applied to networked technologies. Introduction to the basics of these techniques and their applications in networked systems. Development of a network science for solving practical problems pertaining to various networked systems such as smartphones, Wiki, Facebook, recommendation systems, economic network, or online video/music streaming software.
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Crd)

ECE 4704 - Principles of Robotics Systems (3 credits)
Introduction to the design, analysis, control, and operation of robotic mechanisms. Introduction to the use of homogeneous coordinates for kinematics, dynamics, and camera orientation; sensors and actuators, control, task planning, vision, and intelligence. II
Prerequisite(s): ECE 2714
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4805 - Senior Design Project (3 credits)
Industry-like two-semester, team-based major design experience applying knowledge and skills acquired in previous coursework. Design and implement solutions to meet multiple realistic constraints; design to incorporate appropriate engineering standards. A specific, complex engineering design problem is taken from problem definition to product realization and testing. Within the design process, topics include written/oral communication, discourse, ethical reasoning, professional development, project management, and working within a team. 4805: Identify, formulate, and define engineering problem. Generate and select design alternatives. Apply design and analysis methods, from previous courses, to develop, evaluate, and communicate detailed project design. 4806: Implement and refine project design from ECE 4805. Test, analyze, document, and deliver the resulting project outcomes. Pre: 2804 (C-), (12 credit hours of C- or better within their declared disciplinary major) or (9 credit hours of C- or better within their declared disciplinary major and 3 credit hours of C- or better within their secondary focus) for 4805; 4805 (C-) for 4806.
Prerequisite(s): ECE 2214 and ECE 2564 and ECE 2714 and ECE 2804 and (ECE 3004 or ECE 3504) and (ECE 3105 or ECE 3514) and (ECE 3106 or ECE 3134 or ECE 3204 or ECE 3214 or ECE 3304 or ECE 3544 or ECE 3564 or ECE 3574 or ECE 3614 or ECE 3704 or ECE 4205 or ECE 4234 or ECE 4254 or ECE 4424 or ECE 4524 or ECE 4540 or ECE 4580 or ECE 4704)
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4806 - Senior Design Project (3 credits)
Industry-like two-semester, team-based major design experience applying knowledge and skills acquired in previous coursework. Design and implement solutions to meet multiple realistic constraints; design to incorporate appropriate engineering standards. A specific, complex engineering design problem is taken from problem definition to product realization and testing. Within the design process, topics include written/oral communication, discourse, ethical reasoning, professional development, project management, and working within a team. 4805: Identify, formulate, and define engineering problem. Generate and select design alternatives. Apply design and analysis methods, from previous courses, to develop, evaluate, and communicate detailed project design. 4806: Implement and refine project design from ECE 4805. Test, analyze, document, and deliver the resulting project outcomes. Pre: 2804 (C-), (12 credit hours of C- or better within their declared disciplinary major) or (9 credit hours of C- or better within their declared disciplinary major and 3 credit hours of C- or better within their secondary focus) for 4805; 4805 (C-) for 4806.
Prerequisite(s): ECE 4805
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (3 Lec, 3 Crd)

ECE 4944 - Cybersecurity Seminar (1 credit)
Theory and practice of cybersecurity problems and solutions for building secure computing hardware, software, and networks. Technical, social and legal aspects of secure systems. Historical and ongoing attacks that spawn real-world responses. Ongoing research in cybersecurity defenses. Senior standing.
Prerequisite(s): ECE 2544 or CS 2505
Instructional Contact Hours: (1 Lec, 1 Crd)

ECE 4964 - Field Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ECE 4974 - Independent Study (1-19 credits)
A minimum in-major GPA of 2.0 is required for enrollment.
Instructional Contact Hours: Variable credit course

ECE 4984 - Special Study (1-19 credits)
A minimum in-major GPA of 2.5 is required for enrollment.
Instructional Contact Hours: Variable credit course

ECE 4984A - Special Study (1-19 credits)
Pathway Concept Area(s): 1A Discourse Advanced
Instructional Contact Hours: Variable credit course

ECE 4994 - Undergraduate Research (1-19 credits)
A minimum GPA of 2.0 in all ECE courses is required for enrollment.
Instructional Contact Hours: Variable credit course