ELECTRICAL & COMPUTER ENGINEERING

Courses

ECE 101. Introduction to Electrical & Computer Engineering II. 0 Hours
Introduction to electrical and computer engineering faculty, facilities, and curriculum. Career opportunities in electrical and computer engineering and areas of specialization are discussed. Second semester seminar.

ECE 201. Circuit Analysis. 3 Hours
Principles of linear circuit analysis and problem solving techniques associated with circuits containing both passive and active components. Includes analysis of linear circuits with direct current (DC) and alternating current (AC) excitation, as well as a study of transient behavior. Course includes an additional mandatory supervised weekly problem session. Prerequisite(s): MTH 168 and sophomore status. Corequisite(s): ECE 201L.

ECE 201L. Circuit Analysis Laboratory. 1 Hour
Laboratory course stressing experimental techniques, laboratory reporting, safety, and instrumentation. Experimental investigation of linear circuit component behavior and the DC, AC, and transient response of linear circuits. Corequisites: ECE 201 or EGR 203.

ECE 203. Introduction to MATLAB Programming. 1 Hour
MATLAB system and development environment, vector and matrix operations using MATLAB, linear algebra and calculus using MATLAB, MATLAB graphics, flow control, symbolic math toolbox. Prerequisite(s): (CPS 132 or CPS 150) or equivalent.

ECE 204. Electronic Devices. 3 Hours
Study of the terminal characteristics of electronic devices and basic single stage amplifier configurations using bipolar junction transistors and field-effect transistors. Analysis of the devices includes a qualitative physical description, volt-ampere curves, and the development of small- and large-signal equivalent circuit models. Prerequisites: EGR 203 or ECE 201. Corequisites: ECE 204L.

ECE 204L. Electronic Devices Laboratory. 1 Hour
Laboratory investigation of electronic devices: diodes, bipolar junction transistors, field-effect transistors and operational amplifiers. Prerequisites: ECE 201 or EGR 203. Corequisites: ECE 204.

ECE 205. Introduction to Semiconductor Engineering. 3 Hours
Microprocessors and Integrated Circuits (ICs) have billions of tiny transistors that serve as unit cells for computing or data storage. This course will introduce students to the basics of semiconductors, semiconductor manufacturing processes, tools, and how different processes are sequenced together to create useful electronic functions. Prerequisites: ECE 201 or ECT 110 or EGR 203 or MEE 205 or PHY 207.

ECE 215. Introduction to Digital Systems. 3 Hours
Introduction to binary systems, logic circuits, Boolean algebra, simplification methods, combinational circuits and networks, programmable logic devices, flip flops, registers, counters, memory elements, and analysis and design of sequential circuits. Corequisites: (EGR 203 or ECE 201 or MEE 205) and ECE 215L.

ECE 215L. Digital Systems Laboratory. 1 Hour
Laboratory investigation of digital logic circuits and systems covered in ECE 215. Logic gate characteristics; combinational logic design and analysis; latches and flip-flops; synchronous and asynchronous sequential logic; simple digital systems. Experiments include design and analysis of digital systems using breadboarding, FPGA boards, modeling and simulation tools, hardware description languages, and logic synthesis tools. Corequisites: (ECE 201 or EGR 203 or MEE 205) and ECE 215.

ECE 300. Professional Development Seminar II. 0 Hours
Junior level professional development seminar. Presentations on contemporary and professional engineering subjects by students, faculty, and engineers in active practice. The seminar addresses topics in key areas that complement traditional courses and prepare distinctive graduates, ready for life and work. Registration required for all junior ECE students. Prerequisite(s): EGR 200 or COP 200.

ECE 303. Signals & Systems. 3 Hours
Mathematical framework associated with the analysis of linear systems including signal representation by orthogonal functions, convolution, Fourier and Laplace analysis, and frequency response of circuits and systems. Prerequisites: (ECE 201 or EGR 203) and (ECE 203 or MEE 114L). Corequisites: MTH 219 and ECE 303L.

ECE 303L. Signals & Systems Laboratory. 1 Hour
Laboratory investigation of signals and systems including signal decomposition, system impulse response, convolution, frequency analysis of systems, and filter design and realization. Prerequisites: (ECE 201 or EGR 203) and (ECE 203 or MEE 114L). Corequisites: ECE 303.

ECE 304. ELECTRONIC SYSTEMS. 3 Hours
Study of cascaded amplifiers, feedback amplifiers, linear integrated circuits, and oscillators including steady state analysis and analysis of frequency response. Prerequisites: ECE 204 and MTH 219. Corequisites: ECE 303 and ECE 304L.

ECE 304L. Electronic Systems Laboratory. 1 Hour
Design, construction and verification of multistage amplifiers, differential amplifiers, feedback amplifiers, passive and active filters, and oscillators. Prerequisites: ECE 204 and MTH219. Corequisites: ECE 303 and ECE 304.

ECE 305. Introduction to Semiconductor Engineering. 3 Hours
Microprocessors and Integrated Circuits (ICs) have billions of tiny transistors that serve as unit cells for computing or data storage. This course will introduce students to the basics of semiconductors, semiconductor manufacturing processes, tools, and how different processes are sequenced together to create useful electronic functions. Prerequisites: ECE 201 or ECT 110 or EGR 203 or MEE 205 or PHY 207.

ECE 314. Fundamentals of Computer Architecture. 3 Hours
Study of computer systems organization, representation of data and instructions, instruction set architecture, processor and control units, memory devices and hierarchy, I/O devices and interfacing peripherals, high- to low-level language mapping, system simulation and implementation, applications and practical problems. Prerequisite(s): CPS 150; ECE 215. Corequisite(s): ECE 314L.

ECE 314L. Fundamentals of Computer Architecture Laboratory. 1 Hour
Laboratory investigation of digital computer architecture covered in ECE 314. Computer sub-systems such as central processing units, control units, I/O units, and hardware/software interfaces will be experimentally considered. Simulation and implementation will be used to study applications and practical problems. Prerequisites: ECE 215 and CPS 150. Corequisites: ECE 314.

ECE 316. Introduction to Electrical Energy Systems. 3 Hours
A broad introduction to electric energy concepts. Generation, transmission, distribution, and utilization of electric energy. Renewable energy, three phase systems, transformers, power electronics, motors and generators. Contemporary topics. Prerequisite(s): ECE 201 or EGR 203 or equivalent.

ECE 332. Electromagnetics. 3 Hours
Study of vector calculus, electro- and magneto-statics, Maxwell's equations, and electromagnetic plane waves and their reflection and transmission from discontinuities. Prerequisites: PHY 206, MTH 218.

ECE 333. Applied Electromagnetics. 3 Hours
Electromagnetic theory applied to problems in the areas of waveguides, radiation, electro-optics and electromagnetic interference and electromagnetic compatibility. Prerequisites: ECE 332 or (PHY 232 and PHY 207).

ECE 334. Discrete Signals & Systems. 3 Hours
Introduction to discrete signals and systems including sampling and reconstruction of continuous signals, digital filters, frequency analysis, the z-transform, and the discrete Fourier transform. Prerequisites: ECE 303 and MTH 219.

ECE 340. Engineering Probability & Random Processes. 3 Hours
Axiomatic probability, derived probability relationships, conditional probability, statistical independence, total probability and Bayes' Theorem, counting techniques, common random variables and their distribution functions, transformations of random variables, moments, autocorrelation, power spectral density, cross correlation and covariance, random processes through linear and nonlinear systems, linear regression, and engineering decision strategies. Prerequisites: MTH 219. Corequisites: ECE 303.

ECE 398. Multidisciplinary Research & Innovation Laboratory. 1-6 Hours
Students participate in 1.) selection and design, 2.) investigation and data collection, 3.) analysis, and 4.) presentation of a research project. Research can include, but is not limited to, developing an experiment, collecting and analyzing data, surveying and evaluating literature, developing new tools and techniques including software, and surveying, brainstorming, and evaluating engineering solutions and engineering designs. Proposals from teams of students will be considered.

ECE 400. Professional Development for Seniors. 0 Hours
Career planning for electrical and computer engineering majors. The job search process, resume preparation, the job interview, professional development. Required of all electrical and computer engineering majors in their junior or senior year. Prerequisites: ECE 300 or COP 101.

ECE 401. Communication Systems. 3 Hours
Study of amplitude, angle, pulse, and digital communication systems including generation, detection, and analysis of modulated signals and power, bandwidth, and noise considerations. Prerequisites: ECE 304 and ECE 303. Corequisites: ECE 340 and ECE 401L.

ECE 401L. Communication Systems Laboratory. 1 Hour
Design, fabrication, and laboratory investigation of modulators, detectors, filters, and associated communication components and systems. Prerequisites: ECE 304 and ECE 303. Corequisites: ECE 401.

ECE 402. Power Electronics. 3 Hours
ECE 402 is a course addressing the power electronic circuit solutions and controls for the emerging energy conversion systems. It will include the applications of such power circuits for renewable energy sources (fuel cell, solar, wind), electric vehicles and airplanes, and power supplies like wireless charger etc. The course introduces the characteristics of different power semiconductor devices and their application to power conversion area, different types of electric power converters topologies and controls like ac-dc rectifiers, dc-dc converters, and dc-ac inverters. Prerequisites: ECE 303 and ECE 304.

ECE 404. Semiconductor Characterization and Metrology. 3 Hours
The course introduces students to the various electrical and optical metrology methods used in semiconductor manufacturing at different stages of the fabrication process, such as Critical Dimension (CD) uniformity and control, wafer and reticle defect inspection, bright field and dark field imaging and inspection. The course introduces students to critical and non-critical defects, printed and non-printed defects. Prerequisites: ECE 205.

ECE 405. Semiconductor Device Fabrication Lab. 3 Hours
Silicon wafer handling; hazardous chemical handling and safety training; MOSFET fabrication process flow design; photomask design; silicon wafer cleaning; UV photolithography process; photoresist spin coating, photomask alignment and exposure; critical dimension inspections; thin film dielectric deposition methods; plasma and wet chemical etching processes; thermal diffusion and ion implantation doping; microscopy inspection and metrology; dicing, die-bonding and wire bonding; probe testing. Prerequisites: ECE 205.

ECE 406. Advanced Semiconductor Manufacturing. 3 Hours
In-depth study in a selected area of semiconductor manufacturing. Topics include advanced lithography and patterning, 3D transistors, flash memory technologies, thin film transistors, inspection, MEMS technology, yield & defect analysis. Students will work one-on-one with faculty to conduct a comprehensive study on a selected semiconductor manufacturing technique through design, modeling and simulation. Prerequisites: ECE 205 and (EOP 404 or ECE 404 or EOP 405 or ECE 405).

ECE 414. Electromechanical Devices. 3 Hours
Properties and theory of electromechanical devices: nonlinear electro-magnetic actuators; rotating machine analysis; field and circuit concepts and direct current, synchronous, and induction machines: special-purpose machines and fractional horsepower machines. Prerequisite(s): ECE 316 or equivalent.

ECE 415. Control Systems. 3 Hours
Study of mathematical models for control systems and analysis of performance characteristics and stability. Design topics include pole-placement, root locus, and frequency domain techniques. Prerequisites: ECE 303 and MTH 219.

ECE 416. Introduction to Industrial Robotic Manipulators. 3 Hours
Topics include homogeneous transformations, direct and inverse kinematics, trajectory generation, and selected topics of robot vision. Prerequisites: ECE 303 and MTH 219.

ECE 420. The Internet of Things. 3 Hours
Introduction to the multi-disciplinary topic of Internet of Things (IoT), a blend of engineering and science. The course begins with a fundamental technical understanding of the IoT architecture. From this foundation, students experience hands-on labs in a team environment with theoretical justification. The applied work features environmental sensor networking with geospatial data. Each surface area in IoT is explored from sensors and embedded devices to protocols and virtual servers highlighted by current trends within IoT. Lastly, the history, software and influential people will be discussed to provide class context. Ultimately, students scaffold their knowledge through a series of labs, team challenges and supporting lectures to create a final business proposal for a real client IoT value proposition.

ECE 431L. Multidisciplinary Design I. 2 Hours
Application of engineering fundamentals to sponsored multidisciplinary-team design projects. In a combination of lecture and lab experiences, students learn the product realization process and project management. Product realization topics include idea generation, proposal development, design specifications, conceptualization and decision analysis. Project management topics include cost estimation and intellectual property management. Design projects progress to the proof of concept and prototype development stages. Prerequisites: MEE students: EGM 303, MEE 321 and (MEE 344 or RCL 578, or MEE 401 or MEE 409), ECE students: ECE 303 and (ECE 304 or ECE 314).

ECE 432L. Multidisciplinary Design II. 3 Hours
One hour lecture and five hours of lab per week. Detailed evaluation of the Product Realization Process focusing on conceptual design, embodiment design, final design and prototyping is taught. Analysis of the design criteria for safety, ergonomics, environment, cost and sociological impact is covered. Periodic oral and written status reports are required. The course culminates in a comprehensive written report and oral presentation. Prerequisites: MEE majors: MEE 431L; CPE majors: ECE 431L and (2 of the following: ECE 334, CPS 444, ECE 340, CPS 356, ECE 449); ELE majors: ECE 431L and (2 of the following: ECE 401, ECE 415, ECE 333, ECE 334, ECE 340).

ECE 441. Digital Integrated Circuit Design. 3 Hours
Integrated circuit design and layout concepts, design methodology, fabrication process and limitations, MOSFET models for digital design, inverter and logic gates, interconnect and delay, combinational circuits, sequential circuits, datapath subsystems, memory circuits, digital phase lock loops. Prerequisites: ECE 303 and ECE 304.

ECE 444. Advanced Digital Design. 3 Hours
An introduction to modern digital hardware logic design using a hierarchical system approach including top-down development process. An introduction to alternative design implementation forms including hardware description languages (HDLs) for the design of simple and complex combinatorial logic circuits and sequential logic designs with finite state machines. Good HDL coding practices such as readability, re-configurability, and efficient execution are emphasized along with the use of programmable logic circuits including Field-Programmable Gate Arrays (FPGAs). Prerequisite(s): ECE 215.

ECE 445. Signal Processing. 3 Hours
Selected topics in digital signal and image processing with design projects. The design projects are determined by the instructor and may come from a variety of signal processing applications including medical image processing, video processing, computer vision, statistical signal processing, speech processing, radar signal processing, etc. Prerequisite(s): ECE 334.

ECE 446. CMOS Analog Circuit Design. 3 Hours
Integrated circuit design concepts and layout; system perspective on analog design; MOS device theory and processing technology; current mirrors and biasing circuits; voltage and current references; single-stage, differential and operational amplifiers; CAD utilization to realize the design process. Prerequisites: ECE 303, ECE 304.

ECE 447. Digital Control Systems. 3 Hours
Analysis and synthesis of feedback control systems including digital compensators. Topics include performance and stability analysis, regulator and servomechanism design using time and frequency domain methods, and digital implementation case studies. Prerequisite(s): ECE 415; ECE 334 or equivalent.

ECE 448. Fiber Optic Communications. 3 Hours
General light guidance principles; ray optics; dispersion; single mode, multimode, and graded index fibers; basic laser and LED source principles; photodetectors; error probability in digital optical systems; rise time analysis; loss budget analysis; local area networks and long haul communication links. Prerequisite(s): ECE 333. Corequisites: ECE 401.

ECE 449. Computer Systems Engineering. 3 Hours
An introduction to advanced computer architecture and computer systems design. Topics include: exploration of principle architecture features of modern computers, pipelining, memory hierarchy, I/O devices, interconnection networks, introduction to parallel and multiprocessor systems, and the use of hardware description languages (HDLs) in system implementation. Prerequisite(s): ECE 314 and CPS 356.

ECE 450L. Projects Laboratory. 1-3 Hours
Project-oriented laboratory applying engineering skills in the design, development, and demonstration of electrical and electronic systems. Prerequisite(s): Permission of project advisor.

ECE 465. Fundamentals of Solid-State Batteries. 3 Hours
Introduction to the fundamental of solid-state, safe, durable, batteries, including working principles of a battery, state-of-the-art battery (Li-ion battery based on liquid-state electrolytes- advantages/disadvantages), battery safety, need for a safe battery system for low-high power applications (electric vehicles / unmanned-/manned aircrafts, space vehicles, etc.), different design of solid-state batteries (planner-stacked, 3 dimensional, etc.), engineering the structural battery (dual functionality system that can carry mechanical load and store energy), characterization methods to evaluate structure / electrical / electrochemical properties of all solid-state battery materials (cathode, anode, electrolytes), interfaces (electrodes/electrolyte), and electrical/ electrochemical testing of complete battery cells. Also, electrical test methods to evaluate solid-state Li-ion battery (including structural battery) performances, etc.), and understanding degradation mechanism of solid-state battery systems (including structural battery) will be discussed. Prerequisites: ECE 303 and ECE 304 or equivalent.

ECE 466. Fundamentals of Hybrid Electrochemical Power. 3 Hours
Introduction to the fundamental of hybrid electrochemical power (battery + capacitor + fuel cell – integrated systems) including working principles of battery, capacitor, lithium-ion capacitor, and fuel cell, advantages/ disadvantages, necessity to hybridize battery / fuel cell / capacitor, electrical hybridization methods, electrochemical testing of hybrid power systems, degradation mechanism, and applications. Hybrid electrochemical power is highly desirable to meet requirements for wide range products (powering electronic gadget to transportation vehicles to space vehicles) requiring low to high power/energy, cycle-life, fast/slow charge/discharge, etc. Prerequisites: ECE 303 and ECE 304 or equivalent.

ECE 471. Contemporary Power Systems & the Smart Grid. 3 Hours
Introduction to electrical power systems; generation, transmission and utilization; power system analysis; power system control; energy management; and an introduction to smart grid technologies. Prerequisite(s): ECE 316 or equivalent.

ECE 472. Smart Grid Technologies. 3 Hours
An introductory study of enabling technologies and energy issues necessary for full realizaton of the Smart Grid. Course topics vary. This course can be taken multiple times. Prerequisite(s): ECE 471 or equivalent.

ECE 476. Introduction to Radar. 3 Hours
Introduction to the radar range equation, fields and Waves, antennas and phased arrays, beamforming, targets, and clutter radar cross-section, fast time, slow time, detection processing, tracking, space-time adaptive processing, FMCW radar, SAR and ISAR, electronic warfare, transmitters, receivers, and signal processors. Prerequisites: ECE 334.

ECE 477. Artificial Neural Networks. 3 Hours
This course introduces the fundamental concepts, mathematical models, design architectures, and learning algorithms of artificial neural networks (ANNs) which learn from examples. ANNs are biologically inspired systems that mimic the structural and perceptual behavior of human brain. The main topics include the structure of an artificial neuron, single layer perceptron and multi-layer perceptron, delta rule and back-propagation learning, radial basis function neural network, support vector machines, recurrent neural networks, auto-associative and hetero-associative memories, adaptive resonance theory, and self-organizing feature map. Prerequisites: (ECE 203 or MEE114L), ECE 334.

ECE 486. Computer Networks. 3 Hours
Introduction to the fundamental of computer networks, including the Open Systems Interconnection reference model, transmission media, medium access protocol, data link protocols, routing, congestion control, applications, and network security. Recommended prerequisite: ECE303.

ECE 487. Wireless Security. 3 Hours
Wireless security is a very important topic and attracting more and more attention from industry, research, and academia. This course gives a comprehensive overview on the recent advances in wireless network and system security. It will cover security issues and solutions in emerging wireless access networks and systems as well as multi-hop wireless networks. Prerequisites: ECE 203 or MEE 114L.

ECE 490. Biomedical Engineering and Healthcare Electronics. 3 Hours
This survey course will introduce students to the interdisciplinary field of Biomedical Engineering. Students will learn about the application of electrical and computer engineering in healthcare solutions. This course is project oriented, covering topics such as: bioethics, anatomy and physiology, biomimetics, skeletal and cardiac biomechanics, biomaterials & prosthetics, biosensors, bioinstrumentation, neuroscience and traumatic brain injury, rehabilitation engineering/assistive technology, biomedical modeling and medical additive manufacturing. Students may have the opportunity to attend industry site visits with internal and external partners in the medical field to apply knowledge learned in the classroom to real-world experiences. Prerequisites: (ECE 201 or EGR 203) or (MEE 298 or MEE 205) or equivalent.

ECE 491. Medical Imaging. 3 Hours
This course will introduce students to the field of Medical Imaging. Students will learn about the different modalities (Ultrasound, X-ray, CT, MRI, Nuclear Medicine) utilized in healthcare and gain an understanding about which techniques are most appropriate for various medical pathology through open-ended clinical case studies. Students may have the opportunity to attend industry site visits with internal and external community partners in the medical field through collaboration with a local community hospital to apply knowledge learned in the classroom to real-world experiences. This course is project oriented, covering topics such as bioinstrumentation, medical image processing, medical additive manufacturing and sustainable healthcare solutions for developing countries. Prerequisites: (ECE 201 or EGR 203 or MEE 205 or equivalent) and (ECE 203 or MEE114L or equivalent).

ECE 493. Honors Thesis. 3 Hours
Selection, design, investigation, and completion of an independent, original research study resulting in a document prepared for submission as a potential publication and a completed undergraduate thesis. Restricted to students in University Honors Program.

ECE 494. Honors Thesis. 3 Hours
Selection, design, investigation, and completion of an independent, original research study resulting in a document prepared for submission as a potential publication and a completed undergraduate thesis. Restricted to students in University Honors Program. Prerequisite(s): ECE 493.

ECE 498. Multidisciplinary Research & Innovation Laboratory. 1-6 Hours
Students participate in 1.) selection and design, 2.) investigation and data collection, 3.) analysis, and 4.) presentation of a research project. Research can include, but is not limited to, developing an experiment, collecting and analyzing data, surveying and evaluating literature, developing new tools and techniques including software, and surveying, brainstorming, and evaluating engineering solutions and engineering designs. Proposals from teams of students will be considered.

ECE 499. Special Problems in Electrical & Computer Engineering. 1-6 Hours
Particular assignments to be arranged and approved by the department chairperson.

ECE 500. Introduction to the Graduate Program in Electrical and Computer Engineering. 0 Hours
Introduction to ECE graduate program, research methods in ECE, technical writing, literature research, ethics, software and resources.

ECE 501. Contemporary Digital Systems. 3 Hours
An introduction to modern digital hardware logic design using a hierarchical system approach including a top-down development process. An introduction to alternative design implementation forms including hardware description languages (HDLs) for the design of simple and complex combinatorial logic circuits and sequential logic designs with finite state machines. Good HDL coding practices such as readability, reconfigurability, and efficient execution are emphasized along with the use of programmable logic circuits including Field-Programmable Gate Arrays (FPGAs). Required Background: ECE215 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisite: ECE 500.

ECE 503. Random Processes. 3 Hours
Random variables as applied to system theory, communications, signal processing and controls. Topics include advanced engineering probability, random variables, random vectors and an introduction to random processes. Required background: ECE 340 or equivalent.

ECE 504. Power Electronics. 3 Hours
The course introduces the characteristics of different power semiconductor devices and their application to power conversion, different types of electric power converters topologies and controls like ac-dc rectifiers, dc-dc converters, and dc-ac inverters. It will also include the applications of such power converters for renewable energy sources, hybrid electric vehicles, and power supplies. Required Background: ECE 204, ECE 316.

ECE 505. Digital Signal Processing. 3 Hours
A study of one-dimensional digital signal processing, including a review of continuous system analysis and sampling. Topics include z-transform techniques, digital filter design and analysis, and fast Fourier transform processing techniques. Required background: ECE 334 or equivalent course.

ECE 506. Microelectronic Devices. 3 Hours
Crystalline structure of matter, quantum mechanics and energy band theory; bulk properties of semiconductors; p-n and metal-semiconductor junctions; bipolar junction transistors; field-effect transistors; heterostructures; optical properties of semiconductors; devices, modeling and applications. Required background: ECE 304 or equivalent.

ECE 507. Electromagnetic Fields I. 3 Hours
Fundamental concepts, wave equation and its solutions; wave propagation, reflection and transmission; potential theory; construction of modal solutions; various electromagnetic theorems: concept of source, uniqueness, equivalence, induction and reciprocity theorems. Required background: ECE 333 or equivalent.

ECE 509. Analysis of Linear Systems. 3 Hours
State variable representation of linear systems and its relationship to the frequency domain representation using transfer functions and the Laplace transform. State transition matrix and solution of the state equation, stability, controllability, observability, state feedback and state observers are studied.

ECE 510. Microwave Circuits for Communications. 3 Hours
Microwave transmission, planar transmission lines, microwave components and filters. Microwave tubes, microwave communication, radar systems, and electronic support measures. Prerequisite(s): ECE 507.

ECE 511. Antennas. 3 Hours
Fundamental principles of antennas; analysis and synthesis of arrays; resonant antennas; broadband and frequency independent antennas; aperture and reflector antennas; applications to radar and communication systems. Prerequisite(s): ECE 507 or equivalent.

ECE 520. The Internet of Things. 3 Hours
Introduction to the multi-disciplinary topic of Internet of Things (IoT), a blend of engineering and science. The course begins with a fundamental technical understanding of the IoT architecture. From this foundation, students experience hands-on labs in a team environment with theoretical justification. The applied work features environmental sensor networking with geospatial data. Each surface area in IoT is explored from sensors and embedded devices to protocols and virtual servers highlighted by current trends within IoT. Lastly, the history, software and influential people will be discussed to provide class context. Ultimately, students scaffold their knowledge through a series of labs, team challenges and supporting lectures to create a final business proposal for a real client IoT value proposition.

ECE 521. Digital Communications I. 3 Hours
Fundamentals of digital transmission of information over noisy channels; modulation schemes for binary and M-ary digital transmission; optimum receivers; coherent and noncoherent detection; signal design; intersymbol interference; error control coding; the Viberti algorithm; channel capacity and Shannon limits on reliable transmission.

ECE 523. Satellite Communications. 3 Hours
Topics related to the theory, design and orbital placement of geostationary and geosynchronous satellites and their communications applications, including transmitters and receivers in the RF, microwave and optical operational windows, the associated modulation and communication strategies, system hardware and international satellite networks. Required background: ECE 507 or permission from instructor.

ECE 528. Avionics, Navigation and Guidance. 3 Hours
Importance and Role of Avionics, Aerodynamics and Aircraft Control, Fly-by-Wire Flight Control, Inertial Sensors and Attitude Derivation, Navigation Systems, Air Data and Air Data Systems, and Avionics Systems Integration.

ECE 530. Digital Integrated Circuit Design. 3 Hours
Integrated circuit design and layout concepts, design methodology, fabrication process and limitations, MOSFET models for digital design, inverter and logic gates, interconnect and delay, combinational circuits, sequential circuits, datapath subsystems, memory circuits, digital phase lock loops. Required background ECE 304.

ECE 531. Analog Integrated Circuit Design. 3 Hours
Integrated circuit design concepts and layout; system perspective on analog design; MOS device theory and processing technology; current mirrors and biasing circuits; voltage and current references; single-stage, differential and operational amplifiers; CAD utilization to realize the design process. Required background: ECE 304 or equivalent.

ECE 532. Embedded Systems. 3 Hours
This course will introduce the student to the concept of embedded systems and the constraints imposed on hard real-time systems. Course will consist of design, development and test of selected hard-deadline hardware and software using Altera's DE2 development boards. The student will design selected hardware interfaces and develop real-time executive and application code in assembly language and C. Each student will design and implement hardware using Verilog HDL. Required Background: ECE 444 or equivalent.

ECE 533. Computer Design. 3 Hours
Design considerations of the computer; register transfer operations; hardware implementation of arithmetic processors and ALU; instruction set format and design and its effect on the internal micro engine; hardware and micro-programmed control design; comparative architectures. Required background: ECE 314 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 536. Microprocessor Applications. 3 Hours
Project studies, applications of microprocessors in practical implementations; logic implementation using software; memory-mapped I/O problems and interrupt structure implementation; use of compilers; study of alternate microprocessor families including industrial controllers. Required background: ECE 314 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 538. Object-Oriented Programming Applications. 3 Hours
A semi-formal approach to the engineering applications of object-oriented programming. Application of the concepts of classes, inheritance, polymorphism in engineering problems. Introduction to the use of class libraries. Effective integration of the concepts of application programmer interfaces, language features, and class libraries. The required background is C programming experience. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 545. Automatic Control. 3 Hours
Study of mathematical methods for control systems and analysis of performance characteristics and stability. Design topics include pole-placement, root locus, and frequency domain techniques. The student will also learn feedback loop sensitivity, basic loop shaping, performance bounds, and other introductory aspects of robust control. The required background is ECE 415 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 547. Non-Linear Systems & Control. 3 Hours
Introduction to nonlinear phenomena in dynamical systems. A study of the major techniques of nonlinear system analysis including phase plane analysis and Lyapunov stability theory. Application of the analytical techniques to control system design including feedback linearization, backstepping, and sliding mode control. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 549. Engineering Systems for the Common Good. 3 Hours
In this course we will mathematically examine a number of social systems and develop quantitative models describing their behavior. We will review and learn fundamental systems theory concepts, such as block diagrams, feedback loops, and continuous and discrete-time dynamics, as needed. You will apply these concepts to mathematically model and analyze social systems, and in this process, you will learn how the powerful ideal of Human Rights is understood via social system models. You will learn how to study and numerically simulate social dynamics in a methodical, mathematical manner. You will use simulation software to numerically investigate and understand social systems such as sustainability, homelessness, environmental justice, the poverty cycle, and others. For each system, we will highlight its connections to specific human rights. At the conclusion of the course, you will have achieved a deeper understanding of the connection between engineering principles and tools, human rights, and the common good. Required background: differential equations; ECE509 or ECE547 (or equivalent).

ECE 550. Artificial Neural Networks. 3 Hours
This course introduces the fundamental concepts, mathematical models, design architectures, and learning algorithms of artificial neural networks (ANNs) which learn from examples. ANNs are biologically inspired systems that mimic the structural and perceptual behavior of the human brain. Artificial neural networks are the basis and foundation of deep learning systems.

ECE 552. Visual Perception for Autonomy. 3 Hours
This course introduces the fundamental concepts and models of visual perception for autonomous systems with a practical treatment of design, development, implementation, and applications of algorithms for scene analysis and understanding. The class will briefly cover topics in visual data analysis, color perception, region localization, visual feature extraction, visual recognition, perceptual manifolds, motion perception, and visual tracking. Required Background: ECE445 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 554. Applied Robotics. 3 Hours
Within this course, focus will be on project-based learning with robotic systems. Extensive usage of student kits and industrial robotic platforms will enable hands-on learning experiences, which will encourage students to think critically and deepen their knowledge through experimentation. Using a combination of online learning content and classroom lectures, multiple comprehensive projects will be covered, such as a drawing robot, a webcam-controlled rover or industrial arm, and/or a self-balancing motorcycle. Students will use software (MATLAB, Simulink, ROS) programming to implement model-based design, control systems, image and signal processing, and more. The major learning objective is for students to get prepared for real-life environments by using the same tools as industry professionals. Students are expected to have completed a linear algebra course.

ECE 557. Autonomous Systems. 3 Hours
At the intersection of mechanical engineering, electrical engineering, and computer science, autonomous systems involve the implementation of mechatronic technologies which operate independently (autonomously) from human intervention. This course emphasizes the practical implementation of modern control systems for the purposes of creating fully- or semi-autonomous systems. Topics include programming syntax and structure, integration of peripherals (sensors and actuators) with controllers, and data communications both within and external to the systems. Equal mix of lecture and laboratory with significant time dedicated to advanced design projects. Students are expected to have an undergraduate level background in controls and electronics.

ECE 558. Robot Modeling. 3 Hours
This course covers the fundamentals of modeling the movement of spatial systems with a focus on robots, particularly industrial robots. Topics include planar and spatial robotics, forward kinematics including the Denavit-Hartenberg formalism, inverse kinematics, manipulator velocities and the robotics-specific Jacobian, static loads in robots, and the product-of-exponentials formalism. Students are expected to have completed a linear algebra course.

ECE 560. Computational Imaging. 3 Hours
Computation imaging refers to a modality of image capture where image signals are measured not by direct means, but indirectly by a co-designed combination of image acquisition hardware and post-capture processing techniques. Hardware designs may involve modifications to conventional optics and sensor hardware, or using the optics and sensor hardware in an unusual way. Post-capture processing addresses the "inverse problems" within the computational imaging systems designed to estimate the image signal from the measured sensor data. In this class, students will learn how to design calibration experiments, will capture scenes and objects using real hardware, and will develop algorithms to recover the image signal. The class topics may include various modalities of computational imaging, including hyperspectral imaging, digital camera processing pipeline, time of flight cameras, lightfield imaging, structured light imaging, polarization imaging, neuromorphic cameras, and spherical imaging. Required background: ECE 334 (Discrete Signals & Systems) or ECE 505 (Digital Signal Processing), or equivalent.

ECE 563. Image Processing. 3 Hours
An introduction to image processing including the human visual system, image formats, two-dimensional transforms, image restoration, and image reconstruction. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 505. Corequisites: ECE 500.

ECE 564. 3D Computer Vision. 3 Hours
Develop the skills needed to generate synthetic images of 3D objects and to recover 3D structure from one or more views (projections) of 3D objects. Feature recognition in 2D views (images) of a scene based either on actual photographs or synthetic images (computer graphics generated). Applications in robot pose recognition and mobile robot navigation. Students should have experience with MATLAB programming and image processing. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 565. Fundamentals of Solid-State Batteries. 3 Hours
Introduction to the fundamental of solid-state, safe, durable, batteries, including working principles of a battery, state-of-the-art battery (Li-ion battery based on liquid-state electrolytes- advantages/disadvantages), battery safety, need for a safe battery system for low-high power applications (electric vehicles / unmanned-/manned aircraft, space vehicles, etc.), different design of solid-state batteries (planner-stacked, 3 dimensional, etc.), engineering the structural battery (dual functionality system that can carry the mechanical load and store energy), characterization methods to evaluate structure / electrical/ electrochemical properties of all-solid-state battery materials (cathode, anode, electrolytes), interfaces (electrodes/electrolyte), and electrical/ electrochemical testing of complete battery cells. Also, electrical test methods to evaluate solid-state Li-ion battery (including structural battery) performances, etc.), and understanding the degradation mechanism of solid-state battery systems (including structural battery) will be discussed. Required background: ECE 304 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 566. Fundamentals of Hybrid Electrochemical Power. 3 Hours
Introduction to the fundamentals of hybrid electrochemical power (battery + capacitor + fuel cell – integrated systems) including working principles of batteries, capacitors, lithium-ion capacitors, and fuel cells. Discussion of the advantages/disadvantages, necessity to hybridize batteries, fuel cells, capacitors. Electrical hybridization methods, electrochemical testing of hybrid power systems, degradation mechanism, and applications. Hybrid electrochemical power is highly desirable to meet requirements for a wide range of products (such as electronic gadgets, transportation vehicles, and space vehicles) requiring low to high power/energy, cycle-life, fast/slow charge/discharge, etc. Required background: ECE 304 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 567. Machine Learning & Patterning. 3 Hours
This course introduces the fundamental concepts and models of machine learning with a practical treatment of design, analysis, implementation, and applications of algorithms that learn from examples. Topics include supervised and unsupervised learning, self-organization, pattern association, feed-forward, and recurrent architectures, manifold learning, dimensionality reduction, and model selection. Required background in ECE445 or Graduate Student status. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 568. Detection and Estimation. 3 Hours
This course will provide a fundamental understanding of detection, estimation, and their use in solving engineering problems. Students will be able to solve problems involving hypothesis testing, develop a discrete-time signal detector, and compute optimum parameter estimates. Students will become familiar with foundational concepts of likelihood ratio, randomized decision, sufficient statistic, Cramer-Rao bounds, and risk estimation. Students will also develop an understanding of linear least square estimation, minimum mean square estimation, minimum mean absolute error estimation, maximum a posteriori estimation, maximum likelihood estimation, minimum variance unbiased estimation, empirical Bayes estimation, and minimum risk shrinkage operator estimation, expectation-maximization algorithm. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503. Corequisites: ECE 500.

ECE 569. Advanced Random Processes. 3 Hours
This course will provide students with a fundamental understanding of probability, random variables, and random processes, and their use in solving engineering problems. Students will be able to solve problems involving various noise processes and their probability distributions, describe random signals and will analyze linear systems with stochastic inputs. Some advanced topics such as Wiener filtering, Kalman filtering, and Karhunen-Loeve decomposition will be covered. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503. Corequisites: ECE 500.

ECE 572. Optical Information Processing. 3 Hours
Mathematical techniques pertaining to linear systems theory; Fresnel and Fraunhoffer diffraction; Fourier transform properties of lenses; frequency analysis of optical systems, spatial filtering, applications such as optical information processing and holography. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 573. Photonic Devices & Systems. 3 Hours
Solid-state theory of optoelectronic devices; semiconductor photo emitters; LED's, optical amplifiers and semiconductor lasers; photodetectors: PIN, APD, photocells, PMT, detection, and noise; solar cells; cameras and displays; electro-optic and magneto-optic devices; integration and application of electro-optical components in systems of various types. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 507 or permission of department chairperson. Corequisites: ECE 500.

ECE 574. Guided Wave Optics. 3 Hours
Light propagation in slab and cylindrical waveguides; signal degradation in optical fibers; optical sources, detectors, and receivers; coupling; transmission link analysis; fiber fabrication; fiber sensor and communication systems. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 507 or permission of department chairperson. Corequisites: ECE 500.

ECE 576. Introduction to Radar. 3 Hours
Introduction to the radar range equation, fields and Waves, antennas and phased arrays, beamforming, targets, and clutter radar cross-section, fast time, slow time, detection processing, tracking, space-time adaptive processing, FMCW radar, SAR and ISAR, electronic warfare, transmitters, receivers, and signal processors. Required background: ECE303, ECE332, ECE340, or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 577. Introduction to Electronic Warfare (EW). 3 Hours
Overview of the Principles of Electronic Warfare (EW). Review of radar (and radio frequency communication) systems engineering, including fields and waves, waveforms, antennas and array beamforming, target detection and image processing, tracking, space-time adaptive processing (STAP), synthetic aperture radar (SAR), Inverse SAR (ISAR). Principles of direction finding (DF), Electronic Attack (EA) of MTI (moving target indication) radar, SAR, and digital radio frequency memory (DRFM). Principles of Electronic Protection (EP) in MTI and SAR. Low Probability of Intercept (LPI) radar and communications, Electronic Intelligence and STAP, Electronic Support Measures (ESM). Required Background: ECE303, ECE332, ECE340, or equivalent. Recommended: ECE576. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 578. Advanced Radar. 3 Hours
Review of the radar range equation, fields and waves, antennas and phased arrays, beamforming, targets and clutter radar cross-section, fast time, slow time, detection processing, tracking, frequency modulated continuous wave (FMCW) radar, synthetic aperture radar (SAR) and Inverse SAR (ISAR), electronic warfare (EW), transmitters, receivers, and signal processors. Advanced space-time adaptive processing (STAP) techniques, including the Generalized Likelihood Ratio Test, Non-Homogeneity Detection, Knowledge-Based STAP, and Constant False Alarm Rate detection processing. Required Background: ECE303, ECE332, ECE340 or equivalent. Recommended: ECE576. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 580. Principles of Nanofabrication. 3 Hours
Basic principles of processes used in microelectronic and photonic device fabrication: vacuum systems, plasma processes, physical and chemical vapor deposition, properties of silicon and other substrate materials, photolithography and non-optical lithography, wet chemical, and plasma etching, thermal oxidation of silicon, semiconductor doping, ion implantation, metallization, electrical contacts, and micro-metrology. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 581. Nanoelectronics. 3 Hours
Introduction to the physics of materials on the nanoscale; quantum confinement theory; electronic and optical properties of semiconductor nanostructures; single-electron transistors (SETs); tunneling and ballistic devices; nanostructured LEDs, photodetectors, and lasers; nanophotovoltaics and nanomagnetics; quantum computing and molecular electronics; nanoelectronic fabrication, state-of-the-art, and emerging nanoscale devices and applications. Required background in ECE 506 or equivalent. Corequisites: ECE 500.

ECE 583. Advanced Photovoltaics. 3 Hours
Science and applications of photovoltaics, with special emphasis on inorganic and organic semiconductors, ferroelectrics, chalcopyrites, metamaterials, quantum structures, and photovoltaics archictecture. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 506 or permission of instructor. Corequisites: ECE 500.

ECE 586. Computer Networks. 3 Hours
Introduction to the fundamental of computer networks, including the Open Systems Interconnection reference model, transmission media, medium access protocol, data link protocols, routing, congestion control, applications, and network security. Required background: ECE 303 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 587. Wireless Security. 3 Hours
Wireless security is a very important topic and attracting more and more attention from industry, research, and academia. This course gives a comprehensive overview of the recent advances in wireless network and system security. It will cover security issues and solutions in emerging wireless access networks and systems as well as multi-hop wireless networks. Required background: ECE203 or equivalent. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 590. Biomedical Engineering and Healthcare Electronics. 3 Hours
This survey course will introduce students to the interdisciplinary field of Biomedical Engineering. Students will learn about the application of electrical and computer engineering in healthcare solutions. This course is project oriented, covering topics such as: bioethics, anatomy and physiology, biomimetics, skeletal and cardiac biomechanics, biomaterials & prosthetics, biosensors, bioinstrumentation, neuroscience and traumatic brain injury, rehabilitation engineering/assistive technology, biomedical modeling and medical additive manufacturing. Students may have the opportunity to attend industry site visits with internal and external partners in the medical field to apply knowledge learned in the classroom to real-world experiences. Required background: Introduction to Circuits (ECE 201 or EGR 203) or Introduction to Mechatronics (MEE 298 or MEE 205) or equivalent.

ECE 591. Medical Imaging. 3 Hours
This course will introduce students to the field of Medical Imaging. Students will learn about the different modalities (Ultrasound, X-ray, CT, MRI, Nuclear Medicine) utilized in healthcare and gain an understanding about which techniques are most appropriate for various medical pathology through open-ended clinical case studies. Students may have the opportunity to attend industry site visits with internal and external community partners in the medical field through collaboration with a local community hospital to apply knowledge learned in the classroom to real-world experiences. This course is project oriented, covering topics such as bioinstrumentation, medical image processing, medical additive manufacturing and sustainable healthcare solutions for developing countries. Required background: Introduction to Circuits (ECE 201 or EGR 203) or Introduction to Mechatronics (MEE 298 or MEE 205) or equivalent. Introduction to MATLAB Programming (ECE 203) or equivalent.

ECE 595. Special Problems in Electrical Engineering. 1-6 Hours
Particular assignments to be arranged and approved by the department chair. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 599. Thesis. 1-6 Hours
Thesis in Electrical and Computer Engineering. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Corequisites: ECE 500.

ECE 604. Advanced Power Electronics. 3 Hours
The course provides the characteristics and detailed design of power semiconductors, power conversion typologies, and controls. Passive components design and selection and optimization, advanced control strategy and typologies of DC-DC converter and DC-AC Inverters. Prerequisites: ECE 402 or 504.

ECE 633. Advanced Computer Architecture. 3 Hours
Examination of modern high-performance computing architectures, including out-of-order execution RISC multicore processors and GPGPUs. Design projects integrate the concepts learned in class. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 533. Corequisites: ECE 500.

ECE 642. Optimal Control & Estimation. 3 Hours
Introduction to optimal control, starting with dynamic programming for stochastic optimal control; continuous-time optimal control, including Pontryagin's Maximum Principle and its application to the linear case, leading to linear optimal control. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 509 or permission of instruction. Corequisites: ECE 500.

ECE 645. Adaptive Control. 3 Hours
On-line approximation based adaptive control techniques for nonlinear systems. An introduction to neural networks and fuzzy systems as part of the control loop is given, leading to a diversity of advanced methods for controlling and stabilizing nonlinear systems subject to uncertainties. Adaptive observers and adaptive output feedback are also introduced. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 547 or permission of instructor. Corequisites: ECE 500.

ECE 661. Statistical Signal Processing. 3 Hours
This course studies discrete methods of linear estimation theory. Topics include random vectors, linear transformations, linear estimation theory, optimal filtering, least-squares techniques, linear prediction, and spectrum estimation. Concurrency Requirement: Students must be enrolled in or have completed ECE 500 to register for this course. Prerequisites: ECE 503, ECE 505. Corequisites: ECE 500.

ECE 675. SILICON PHOTONICS. 3 Hours
Photonic Integrated Circuits and Components on the silicon platform, Optical fiber coupling into single mode waveguides, Power Splitting Components, Polarization Manipulation Components, Integrated Photonic Thermo-Optic, and Electro-Optic Modulators, Photonic Circuit Modeling , Silicon Photonics Foundry Fabrication, Design Project with Ansys/ Lumerical software. Prerequisites: ECE 333 or equivalent or Permission of Instructor.

ECE 695. Special Problems in Electrical and Computer Engineering. 1-6 Hours
Special topics in electrical engineering not covered in regular courses. Course sections arranged and approved by the chair of the student's doctoral advisory committee and the department chair.

ECE 696. Graduate Seminar. 0-3 Hours
Research oriented independent study course intended for doctoral level graduate students. The student will perform an in-depth research on a selected topic of mutual interest with his/her doctoral adviser, and achieve sufficient expertise to do a technical presentation about the topic in front of his/her peers. The student will prepare a report and present it in one of the graduate seminar sessions during the semester. The student is expected to attend all the seminars presented by other graduate students during the semester and to interact with them to improve the depth and breath of his/her knowledge.

ECE 699. PhD Dissertation. 1-15 Hours
Original research in electrical engineering that makes a definite contribution to technical knowledge. Results must be of sufficient importance to merit publication in a refereed journal.