Electrical Engineering

Undergraduate Degrees

- Bachelor of Science in Electrical Engineering (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/undergraduate/)
- Minor in Electrical Engineering (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/undergraduate/)

Graduate Degrees

- Electrical Engineering, M.Engr. Non-Thesis (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#masterstext)
- Electrical Engineering, M.S. (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#masterstext)
- Electrical Engineering, M.S. Fast Track (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#masterstext)
- Electrical Engineering, B.S. to Ph.D. (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#doctoraltext)
- Electrical Engineering, Ph.D. (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#doctoraltext)

Certificates

- Graduate Certificate in Power System Management (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#certificatestext)
- Graduate Certificate in Photonic Devices and Systems (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#certificatestext)
- Graduate Certificate in Embedded Systems (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/graduate/#certificatestext)
- Undergraduate Certificate in Embedded Systems (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/undergraduate/#certificatestext)
- Undergraduate Certificate in Unmanned Vehicle Systems (http://catalog.uta.edu/archives/2022-2023/engineering/electrical/undergraduate/#certificatestext)

COURSES

EE 1000. FRESHMAN UNDERGRADUATE RESEARCH. 0 Hours.
Freshman level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 1101. INTRODUCTION TO ELECTRICAL ENGINEERING. 1 Hour.
After an introduction to different branches of Engineering, we focus on Electrical Engineering to illustrate concepts, methods, problem solving approach, and tools common to all Engineering, and those unique to Electrical Engineering. Various areas within Electrical Engineering will be introduced, with examples from analog and digital electronic circuits, control and robotics, microwave and optical engineering, telecommunication, energy systems, and biosensors. Students will be introduced to skills they need to succeed in subsequent Engineering courses, and ethical responsibilities. The emphasis is to engage students in active learning through exercises, mini-projects, and team activities. Selected speakers from across the College of Engineering will make presentations and emphasize the interdisciplinary nature of Engineering. Some College of Engineering requirements are satisfied by the content of this course.

EE 1106. ELECTRICAL ENGINEERING FRESHMAN PRACTICUM. 1 Hour.
A project-based course focuses on basic methods for manipulating voltages and currents to achieve specific application objectives. Basic concepts covered include circuit elements and abstractions, circuit topology and analysis methods. Students will engage in laboratory experiments and learn how to conduct a variety of measurements including voltage, current, waveform, and frequency/spectrum measurements. Prerequisite: Grade of C or better in EE 1201 (or concurrent enrollment).

EE 1201. INTRODUCTION TO ELECTRICAL ENGINEERING. 2 Hours.
This course introduces basic concepts in electrical engineering (EE) and their applications through laboratory experiments and hands-on projects. The course provides some background of the respective subareas within EE, including overviews of and motivations for analytical tools that will be developed throughout EE curriculum. Prerequisite: Grade C or better in MATH 1426 (or concurrent enrollment).

EE 1311. COMPUTING SYSTEM AND ALGORITHMIC SOLUTIONS. 3 Hours.
This course focuses on algorithmic problem solving and implementation of the algorithm using C or Python Programming Language. Fundamental concepts covered in this course include computing system architecture, operating systems, program execution, algorithm and flowchart, data structure, numerical methods, and hardware interfacing. Prerequisite: Grade C or better in MATH 1426 (or concurrent enrollment).

EE 2000. SOPHOMORE UNDERGRADUATE RESEARCH. 0 Hours.
Sophomore level undergraduate research course. Prerequisites: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 2181. CIRCUIT ANALYSIS LABORATORY. 1 Hour.
Circuits laboratory for non-electrical engineering majors. This is identical to the laboratory portion of EE 2440. Prerequisite: Grade C or better in MATH 2425. Corequisite: EE 2320 and PHYS 1444.

EE 2240. SOPHOMORE PROJECT LABORATORY. 2 Hours.
A project based experiential learning course that provides an opportunity for students to explore and develop comprehensive applications of electrical engineering concepts and technologies to address real-world needs. Students will work in teams and engage in project planning, management, presentation, reporting, and outcome assessment. Prerequisite: Grade of C or better in each of the following: EE 1311, EE 2315, EE 2303 (or concurrent enrollment), EE 2341 (or concurrent enrollment), and EE 2347 (or concurrent enrollment).

EE 2302. PRINCIPLES OF ACTIVE AND PASSIVE DEVICES. 3 Hours.
This course covers electric and magnetic properties of solid materials with applications in the design and fabrication of active and passive devices. Topics include charge carriers, drift and diffusion currents, electrostatics, magnetostatics, dielectric/conductor/semiconductor properties, magnetic domain, Hall effects, passive circuit elements, electronic energy band diagrams, p-n junction, diode, FET, LED, semiconductor lasers, sensor and device applications. Prerequisite: Grade of C or better in both CHEM 1465 and EE 2315.

EE 2303. ELECTRONICS I. 3 Hours.
Introduction to semiconductors, drift and diffusion current, and p-n junction. Electrical characteristics of diodes, bipolar junction transistors (BJTs), and field-effect transistors (FETs). Circuit applications: switches, square-law detector, and amplifier. Digital and analog electronic circuits. Logic circuits. Single and multistage electronic circuit analysis and design. Amplifier operating point and frequency response. Low frequency and high frequency analysis and design. Prerequisite: Grade C or better in each of the following EE 2302 (or concurrent enrollment), EE 2315 and MATH 3319.

EE 2315. CIRCUIT ANALYSIS I. 3 Hours. (TCCN = ENGR 2305)
This course covers fundamental concepts and applications in manipulating voltage and current using passive and active circuit elements. Circuit models for passive (lumped) elements (resistor, capacitor, and inductor); independent and dependent sources; switches and active elements (diode and transistor). Circuit topology, governing laws (KCL and KVL), and node and mesh analysis methods. Time-varying and time-harmonic analyses of 1st order and 2nd order passive circuits. Steady-state alternating-current (AC) phasor analysis. Frequency domain analysis and Bode plots. Properties and applications of diode and transistor. Rectifier and switches. Higher level abstractions: Thevenin and Norton equivalents, and op-amps. Properties and applications of op-amps. Computer-assisted circuit analysis and design. Prerequisite: Grade C or better in each of the following: EE 1106, MATH 2425, MATH 3319 (or concurrent enrollment) and PHYS 1444 (or concurrent enrollment).

EE 2320. CIRCUIT ANALYSIS. 3 Hours.
For non-electrical engineering majors. Basic principles of R, L, and C components. Kirchhoff's laws, network analysis, loop and node equations, basic network theorems. Steady-state Alternating Current (AC) phasor analysis, operational amplifiers, filtering, and digital circuits. Prerequisite: Grade of C or better in each MATH 2425 or HONR-SC 2425 and PHYS 1444.

EE 2341. DIGITAL CIRCUITS AND SYSTEMS. 3 Hours.
An introduction to digital system design with hands-on projects. Number systems and codes. Boolean algebra; combinatorial logic and arithmetic. Digital electronics; CMOS logic gates; digital signals and noise margin; logic gates; and combinatorial logic circuits. Timing hazard and delay. Programmable logic devices; VHDL. State machines; sequential logic elements; counters and shift registers; sequential logic circuits. Arithmetic and computer logic circuits. Prerequisite: Grade C or better in each of the following: EE 1311 and EE 2315 (or concurrent enrollment).

EE 2347. MATHEMATICAL FOUNDATIONS OF ELECTRICAL ENGINEERING. 3 Hours.
This course focuses on mathematical modeling and algorithmic thinking to solve electrical engineering problems and interpret the results. Concepts covered in this course include mathematical representation of electrical signal and system behavior, complex analysis, Fourier series and Fourier transformations, computational modeling using MATLAB or Python, data processing and analysis. Prerequisite: Grade of C or better in each of EE 1311, MATH 2425, and MATH 3319.

EE 2403. ELECTRONICS I. 4 Hours.
Introduction to semiconductors, carrier statistics, drift and diffusion, semiconductor diodes, bipolar junction transistors (BJTs), and field-effect transistors (FETs). Circuit applications of diodes. Direct Current (DC) biasing and stability of circuits containing diodes, BJTs, and FETs. Introduction to mid-band single stage small signal analysis of BJT and FET circuits. Laboratory experiments to complement concepts learned in class. Prerequisite: Grade C or better in both EE 2415 and MATH 2326.

EE 2415. CIRCUIT ANALYSIS I. 4 Hours.
Basic circuit concepts of resistor, inductor, and capacitor (RLC) components. Kirchhoff's laws, resistive network analysis, power calculations, loop and node equations, topology, basic network theorems. Dependent sources and operational amplifiers. Computer-assisted solution of circuit problems. Elementary transient time-domain analysis. Introduction to frequency domain analysis and Bode plots. Steady state A-C phasor analysis, including element laws and phasor diagrams. Problems and experimental demonstrations will be covered during recitation and laboratory sessions. Prerequisite: Grade C or better in EE 1106 and MATH 2425. Co-requisite: MATH 3319 and PHYS 1444.

EE 2440. CIRCUIT ANALYSIS WITH LAB. 4 Hours. (TCCN = ENGT 1401)
For non-electrical engineering majors. Basic principles of R, L, and C components. Kirchhoff's laws, network analysis, loop and node equations, basic network theorems. Steady-state AC phasor analysis, operational amplifiers, filtering, and digital circuits. Concurrent laboratory experiments complement lecture topics. Prerequisite: Grade C or better in MATH 2425 and PHYS 1444.

EE 2441. DIGITAL DESIGN AND PROGRAMMABLE MICROCONTROLLERS. 4 Hours.
Theory and design of digital logic circuits. Number systems and binary arithmetic. Boolean algebra theorems. Optimization by algebraic and mapping methods. Logic gates, arithmetic logic units, decoders, analysis and synthesis of combinatorial logic circuits, sequential circuits. Synchronous and asynchronous state machines, hazards and races conditions with sequential circuits. Introduction of hardware description language (VHDL). Laboratory consists of "proof of concept" experiments using digital components. Prerequisite: Grade C or better in CSE 1311.

EE 3000. JUNIOR UNDERGRADUATE RESEARCH. 0 Hours.
Junior level undergraduate research. Prerequisite: Departmental good standing and permission of instructor. May be taken a maximum of 3 times.

EE 3140. JUNIOR PROJECT LABORATORY. 1 Hour.
Introduction to electrical engineering design concepts and strategies. Students must complete semester long projects from the areas of sensors, analog, digital, and mixed signal circuits, modules, and systems. Students are expected to use knowledge and skills previously obtained from lecture and laboratory courses (electronics, digital logic and microprocessors, and circuit analysis II) to complete their projects. The project must be well planned with clear performance objectives and constraints. Students are expected to show competency in technical writing and presentation. Prerequisite: Grade of C or better in EE 2403, EE 2441. Prerequisite or concurrent enrollment: EE 3446.

EE 3240. JUNIOR PROJECT LABORATORY. 2 Hours.
Introduction to electrical engineering design concepts and strategies, engineering ethics, and safety. Students must complete semester long projects from the areas of sensors, analog, digital, and mixed signal circuits, modules, and systems. Students are expected to use knowledge and skills previously obtained from lecture and laboratory courses to complete their projects. The project must be well planned with clear performance objectives, constraints, timeline, and deliverables. Students are expected to show competency in technical writing and presentation. Prerequisite: Must be in the professional EE program and Grade of C or better in each of the following: EE 2303, EE 2341, and EE 3346 (or concurrent enrollment).

EE 3302. FUNDAMENTALS OF POWER SYSTEMS. 3 Hours.
Introduction to power systems, three-phase circuit analysis, symmetrical components, transformer, polyphase induction motors, synchronous generators, synchronous motors, diode and diode circuits, thyristor and thyristor circuits, DC-DC switching converters, and DC-AC switching converters, Renewable energy sources. Concurrent laboratory experiments complement the course lecture topics. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 3346 and EE 3407 (or concurrent enrollment).

EE 3310. ADVANCED MICROCONTROLLERS. 3 Hours.
Principles of operation for microcontroller, including assembly language programming, internal architecture of microcontroller, timing analysis, and interfacing techniques. Special emphasis will be placed on hardware-software interactions, design of memory systems for microcontroller and utilization of programmable peripheral devices. Prerequisite: Grade of C or better in EE 2441 and EE 2403.

EE 3314. FUNDAMENTALS OF EMBEDDED CONTROL SYSTEMS. 3 Hours.
Analyses of open-loop and close loop systems using frequency domain and state variable techniques. Analog and digital control design methods. System design requirements and specifications. Design and implementation of control system using programmable devices. Principles of operation for microcontroller, internal architecture, programming tools and techniques, timing analysis, interfacing with sensors and actuators. Real-time control applications. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2341, EE 3316, and EE 3318 (or concurrent enrollment).

EE 3316. CONTINUOUS AND DISCRETE SIGNALS AND SYSTEMS. 3 Hours.
Time-domain and frequency-domain analyses of periodic, aperiodic, continuous, and discrete time signals. Energy and power signals. System abstraction, signal flow and block diagrams. Linear systems, time invariance, causality, stability, and state-space. Laplace transforms. Impulse and frequency responses of LTI systems. LTI system specification and design. Filters and equalizers. Continuous time and discrete time (DT) signal conversion, sampling theorem, aliasing, and quantization error. Discrete-Time Fourier Transform (DTFT). Time and frequency responses of LTI system to DT signals. Interpolation and low-pass filter. Time and frequency domain analyses of DT LTI systems. z-transform. Causality and stability of DT LTI systems. Applications of DT LTI systems, FIR and IIR filters. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347 and EE 2315.

EE 3317. LINEAR SYSTEMS. 3 Hours.
For non-electrical engineering majors. Time-domain transient analysis, convolution, Fourier Series and Transforms, Laplace Transforms and applications, transfer functions, signal flow diagrams, Bode plots, stability criteria, and sampling. Classes meet concurrently with EE 3417. ME Majors Prerequisite: Grade C or better in MATH 3330, ME Majors Corequisite: EE 2320 or equivalent. BE Majors Prerequisite: Grade C or better in MATH 3319.

EE 3318. ANALOG AND DIGITAL SIGNAL PROCESSING. 3 Hours.
Time and frequency domain analyses of continuous-time (CT) and discrete-time (DT) signals and systems. CT and DT Convolution. DTFT, DFT, and z-transforms of signals. Phase shifting, frequency shifting, and group delay. Modeling of stationary random signals utilizing filtered white noise. Power spectral density and SNR. Improving SNR through filtering. Amplitude, phase, and stability of causal and non-causal digital filters. FIR and IIR digital filter design. Applications of discrete time systems. Program assignments in Matlab. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 3316 and EE 3330 (or concurrent enrollment).

EE 3330. PROBABILITY AND STATISTICAL METHODS. 3 Hours.
Probability, random variables, functions of random variables, moments, random signals, noise, stochastic models and power spectral density. Data and statistics. Random sampling. Statistical analysis, hypothesis testing, goodness of fit test, and regression. Response of LTI systems to random signals. Rigorous mathematical concepts will be tied to engineering system issues such as characterizing uncertainty due to measurement error, component and system tolerances, and noise sources such as device noise, quantization noise, communication channel noise, and thermal noise. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347 and EE 3316 (or concurrent enrollment).

EE 3346. CIRCUIT ANALYSIS II. 3 Hours.
Time-harmonic single-phase and poly-phase voltages and currents. Instantaneous, time average, and complex powers. Power factor and maximum power transfer. Independent and dependent sources. Time and frequency domain analyses of open-loop and closed-loop circuits. Feedback configurations, poles and zeros, stability analysis. Oscillators and filters. Two-port networks and network parameters. Network theorems and analyses, superposition, reciprocity. Characteristics and applications of operation amplifiers. Amplifiers and active filters. Distributed networks and transmission lines. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347, EE 2303, and EE 2315.

EE 3407. ELECTROMAGNETICS. 4 Hours.
Time varying electric and magnetic fields; electromagnetic (EM) sources. Laws governing EM fields and sources. Circuit and transmission line. Wave propagation on transmission line. Power flow and impedance matching. Dividers and couplers. Applications of EM theory in energy conversion. Antenna concept, EM wave radiation and polarization. Applications of EM theory in energy conversion. Waves in unbounded medium. Waves in medium with planar interfaces. Wave reflection, transmission, and scattering. Fundamentals and applications of rectangular waveguides. Fundamentals of antenna. Friis' transmission formula. Applications of EM theory in optical transmission, wireless communications, and radar. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2347, PHYS 1444, and EE 3346 (or concurrent enrollment).

EE 3444. ELECTRONICS II. 4 Hours.
Low and high frequency characteristics and circuit models for diodes, bipolar junction transistors (BJTs), and field effect transistors (FETs). Analysis and design of full spectrum small signal BJT and FET circuits. Analysis and transistor level design of active filters, oscillators, feedback configurations, and multistage differential and operational amplifiers. Concurrent laboratory exercises in support of the topics covered in class. Prerequisite: Must be in the professional EE program and C or better in each of the following: EE 2303 and EE 3346.

EE 3446. CIRCUIT ANALYSIS II. 4 Hours.
Analysis and design of filters, oscillators, feedback configurations, and operational amplifiers. Dependent sources, device models, two-port networks, and mutual inductance and transformers. Network response functions, poles and zeros, network theorems, resonance, and the analysis and design of active filters. Application of phasors in steady-state circuit analysis. Introduction to distributed networks and transmission lines. Introduction to single-phase and three-phase balanced and unbalanced power networks, complex power, power factor correction, and maximum power transfer. Concurrent laboratory experiments complement lecture topics. Prerequisite: Grade C or better in EE 2347 and EE 2415.

EE 4000. UNDERGRADUATE RESEARCH. 0 Hours.

EE 4149. ENGINEERING DESIGN PROJECT. 1 Hour.
A practicum resulting in the design, construction, and evaluation of a device or system, building on electrical or electronic knowledge and skills acquired in earlier course work, and incorporating appropriate engineering standards. The application of project management techniques in order to meet design specifications through the effective allocation of team resources, scheduling, and budgetary planning. The demonstration of the finished product/prototype through both oral presentation and a written project report. Mode of Instruction: Practicum. Prerequisite: Must be in the professional EE program and Grade of C or better in EE 4240. Grade of C or better in all prior 3000 and 4000 level EE coursework.

EE 4240. CONCEPTS & EXERCISES IN ENGINEERING PRACTICE. 2 Hours.
Integration of technical knowledge and skills with project planning, teamwork, and communication skills (written and oral). A project-oriented approach is used including the preparation of literature-based research reports and project management plans. The differences between research and product development are taught and assessed through short proposal reports. Supporting topics: technical information resources, ethics, safety, intellectual property. Students will begin their engineering capstone design experience, including team formation, project selection, background research, and preparation of preliminary project plan. Must be taken in the semester prior to EE 4149. An EE Proficiency Test is administered during the class. Prerequisite: Must be in the professional EE program and grade of C or better in each of the following: COMS 2302, EE 3240, EE 3314, EE 3318, EE 3330, and EE 3407. Co-requisite ECON 2305.

EE 4301. POWER SYSTEMS ANALYSIS AND CONTROL. 3 Hours.
This course includes an introduction to synchronous machines, power flow analysis, short circuit analysis, power system controls, and the fundamentals of transient stability analysis. Prerequisite: Grade of C or better in EE 3302.

EE 4302. ENGINEERING ENTREPRENEURSHIP. 3 Hours.
Topics include special problems of newly formed firms, planning, start-up business considerations, business strategy, management basics, and business plan design. Students will engage in business and entrepreneurship training and discussion, become aware of basic business operations, and learn about inventions, intellectual property, and the patenting process. Other topics include assessment of possible markets, venture feasibility, teambuilding, and leadership. Opportunities in university environments will be discussed including incubation centers and patent licensing. We address legal issues, Small Business Innovation Research (SBIR) proposal design, SBIR funding from the National Science Foundation (NSF), National Institutes of Health (NIH), and others. Additional topics include the proposal review process, grant reporting, local high-tech business accelerators, angel-group funding, venture plans, and venture capital. Classes will feature lectures from engineering and business faculty as well as presentations by successful entrepreneurs. Course taught as EE 4302, ENGR 4302 and ENGR 5302; credit will be granted only once. Prerequisite: Student must be in an engineering professional program.

EE 4308. POWER SYSTEM MODELING AND ANALYSIS. 3 Hours.
Fundamental concepts for modeling transmission lines, distribution lines, power system generators, power transformers and power system load. The method of symmetrical components is discussed. Simulation of power systems during normal and abnormal conditions are presented. The philosophy of deregulation regarding separation of power systems into generation, transmission and distribution companies is introduced. Prerequisite: Grade of C or better in EE 3302.

EE 4310. MICROPROCESSOR SYSTEMS. 3 Hours.
Hardware/software development techniques for microprocessors with emphasis on asynchronous and synchronous memory interfaces, optimizing data throughput, and modern bus architectures. Topics include DMA controller design, SDRAM controller design, and real-world interfacing. Prerequisite: Grade of C or better in EE 3310.

EE 4311. EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Hardware/software development techniques for microcontroller systems with an emphasis on hardware-software interactions, programming internal peripherals, interfacing with external sensors and devices, and real-time control applications. Prerequisite: Grade of C or better in EE 3310.

EE 4312. ADVANCED MICROPROCESSOR SYSTEMS. 3 Hours.
Study of the advanced microprocessor architectures including 32/64-bit RISC and CISC families of microprocessors will be compared based on detailed architectural analysis of the selected devices. This course may also include: address/instruction pipelines, burst cycles, memory caching and cache coherency issues, register renaming, speculative instruction execution and other performance-oriented techniques. Prerequisite: EE 4311.

EE 4313. CONTROL SYSTEMS FOR NON-EE MAJORS. 3 Hours.
For non-electrical engineering majors. Analyses of closed loop systems using frequency response, root locus, and state variable techniques. Analog and digital control design methods. System modeling, identification, and control design based on analytic and computer methods. Classes meet at the same time as EE 4314. Prerequisite: Grade of C or better in either EE 3317 or MAE 3319.

EE 4314. CONTROL SYSTEMS. 3 Hours.
Analyses of closed loop systems using frequency response, root locus, and state variable techniques. Analog and digital control design methods. System modeling, identification, and control design based on analytic and computer methods. Use of laboratory experiments with mechatronic systems to complement the course lectures. Prerequisite: Grade of C or better in EE 3316. Co-requisite EE 3318.

EE 4315. INTRODUCTION TO ROBOTICS. 3 Hours.
Overview of industrial robots. Study of principles of kinematics, dynamics, and control as applied to industrial robotic systems; robotic sensors and actuators; path planning; programming of industrial robot in the laboratory; survey of robotic applications in various modern and traditional fields; and guidelines to robot arm design and selection. Prerequisite: Grade C or better in EE 4314.

EE 4316. OP AMPS IN ANALOG SIGNAL PATHS. 3 Hours.
The course covers fundamental concepts involved in the analysis and design of a wide variety of linear and non-linear circuits that use bipolar and CMOS integrated circuit operational amplifiers (op-amps). Applications of these components in practical circuit designs are emphasized. Prerequisite: Grade of C or better in EE 3446.

EE 4317. ANALOG CMOS IC DESIGN. 3 Hours.
Analysis and design of CMOS analog integrated circuits; MOS device structure and models; single-state and differential amplifiers; current mirror and Operational Amplifier design; noise analysis and feedback; comparators and voltage references. Prerequisite:Must be in the professional EE program and C or better in each of the following: EE 2303 and EE 3444.

EE 4318. DIGITAL SIGNAL PROCESSING. 3 Hours.
Discrete time convolution. Fast convolution using the fast Fourier transform (FFT). Amplitude and phase of digital filters. Stability analyses using the Z-transform. Design of finite impulse response (FIR) digital filters through windowing and optimization approaches. Infinite Impulse Response (IIR) digital filter design approaches using transformation and optimization. Prerequisite: Grade of C or better in EE 3316 and EE 3318.

EE 4320. DIGITAL VLSI DESIGN. 3 Hours.
Introduction to Very Large Scale Integration circuit design and fabrication technology. Metal-Oxide Semiconductor (MOS) device models and digital integrated circuit design with Metal-Oxide Semiconductor Field-Effect Transistor (MOSFETs). Computer Aided Drafting (CAD) tools for VLSI design. Processing models and process flow. MOS integrated circuits for logic gates and digital systems. Prerequisite: Grade of C or better in EE 3444.

EE 4327. THEORY AND DESIGN OF ANTENNAS. 3 Hours.
Basic theory of antennas with emphasis on design and engineering application. Prerequisite: Grade of C or better in EE 3407.

EE 4328. CURRENT TOPICS IN ELECTRICAL ENGINEERING. 3 Hours.
To introduce current topics into the curriculum prior to the creation of permanent course numbers. A notice listing a descriptive course title, a course description, and the name of the instructor will be posted on the departmental webpage each time the course contents are changed. Prerequisite: Consent of instructor.

EE 4329. SEMICONDUCTOR DEVICES. 3 Hours.
Introduction to semiconductors in terms of atomic bonding and electron energy bands. Equilibrium statistics of electrons and holes. Carrier dynamics; continuity, drift, and diffusion currents; generation and recombination processes, including important optical processes. Introduction to P-N junctions, metal-semiconductor junctions; bipolar junction transistors, junction and Metal-Oxide Semiconductor Field-Effect Transistors (MOSFETs). Introduction to optoelectronic devices, including LEDs, lasers, detectors, solar cells, modulators, etc. Prerequisite: Grade of C or better in EE 3407.

EE 4330. FUNDAMENTALS OF TELECOMMUNICATIONS SYSTEMS. 3 Hours.
Examines analog and digital communication techniques including amplitude modulation, frequency modulation, and pulse code modulation. Time domain and frequency domain multiplexing. Analog and digital noise analysis, information theory. Design of communications systems. Prerequisite: Grade of C or better in EE 3316 and EE 3330. Co-requisite EE 3318.

EE 4331. DATA COMMUNICATIONS ENGINEERING. 3 Hours.
Layered approach to data communications and networking will be presented. Network models such as TCP/IP and OSI will be introduced. Protocols and technologies related to each layer will be studied in depth. For physical layer, analog and digital signaling, modulation, bandwidth, multiplexing as well as line and block coding techniques. For data link layer, various MAC layer protocols involving multiple access, error detection (CRC), wired (Ethernet) versus wireless (Wi-Fi) LANs, switching. For network layer, internet protocol (IP) and routing principle. Underlying technologies learned from this course are applicable to wide range of traditional and current data communication protocols. Performance analysis of well-known protocols using probabilistic model will also be studied. Prerequisite: Grade of C or better in each of the following: EE 3316, EE 3330, and EE 3318 (or concurrent enrollment).

EE 4333. WIRELESS COMMUNICATIONS AND IoT. 3 Hours.
Fundamental principles of radio system design and propagation. Basics of cellular systems, environment, propagation models, traffic models and spectral capacity. Multiple-access techniques including FDMA (frequency division multiple access), TDMA (time division multiple access), CDMA (code division multiple access). Internet of Things (IoT) system architecture, IoT enabling technologies such as sensors and sensor networks, IoT communication and networking protocols, IoT services and applications. IoT demands, impacts, and implications on sensors technologies, big data management, and future internet design for various IoT use cases, such as smart cities, smart environments, smart homes, etc. Prerequisite: Grade of C or better in EE 3316 and EE 3330. Prerequisite or concurrent enrollment in EE 3318.

EE 4334. PROGRAMMABLE LOGIC DESIGN. 3 Hours.
Design of digital systems using programmable logic devices and high-level techniques. The course emphasizes the understanding of state-of-the-art hardware devices as well as design and simulation tools. Hardware description language will be taught and used for digital system design. Various design options and compromises will be explored for typical tasks. Projects will be assigned to develop design proficiency. Prerequisite: Grade of C or better in EE 2341.

EE 4336. FOUNDATIONS OF MEDICAL IMAGING. 3 Hours.
This course introduces the engineering, physics, mathematics, and signal processing methods fundamental to medical image acquisition and processing. X-ray projection, X-ray computed tomography, magnetic resonance imaging, and ultrasound imaging. Brief introduction to optical and infrared imaging and nuclear imaging (SPECT/PET) will be included. Open to students in an engineering or science professional program. Prerequisite: EE 3316 or equivalent.

EE 4339. RADIO FREQUENCY CIRCUIT DESIGN. 3 Hours.
Analysis of waves on ideal transmission lines, assorted practical transmission line systems, and hollow waveguides. Circuit theory for transmission line systems involving scattering parameters and the Smith chart. Microwave impedance matching techniques. Design of lumped element amplifiers from VHF to microwave frequencies. Real world microwave characterization techniques. Prerequisite: Grade of C or better in EE 3444 and EE 3407.

EE 4340. CONCEPTS & EXERCISES IN ENGINEERING PRACTICE. 3 Hours.
Integration of technical knowledge and skills with project planning, teamwork, and communication skills (written and oral). A project-oriented approach is used including the preparation of literature-based research reports, research proposals, product development proposals, and project management plans. Supporting topics: technical information resources, ethics, safety, intellectual property. Students will begin their engineering capstone design experience, including team formation, project selection, background research, and preparation of preliminary project plan. Must be taken in the semester prior to EE 4349 (Engineering Design Project). An EE Proficiency Test will be administered on first day of class. Prerequisite: Grade of C or better in each of COMS 2302, EE 3330, EE 3446, and EE 3407. Corequisite ECON 2305.

EE 4344. INTRODUCTION TO MEMS AND DEVICES. 3 Hours.
Develops the basics for microelectromechanical devices and systems including microsensors, and micromotors, principles of operation, different micromachining techniques, and thin-film technologies as they apply to MEMS. Prerequisite: EE 3407.

EE 4349. ENGINEERING DESIGN PROJECT. 3 Hours.
A practicum resulting in the design, construction, and evaluation of a device or system, building on electrical or electronic knowledge and skills acquired in earlier course work, and incorporating appropriate engineering standards. The application of project management techniques in order to meet design specifications through the effective allocation of team resources, scheduling, and budgetary planning. The demonstration of the finished product/prototype through both oral presentation and a written project report. Mode of Instruction: Practicum. Prerequisite: Grade of C or better in EE 4340. Grade of C or better in all prior 3000 and 4000 level EE coursework.

EE 4357. INTRODUCTION TO MACHINE LEARNING. 3 Hours.
The course presents fundamental principles and techniques on detecting meaningful patterns in data. Supervised learning techniques with applications in regression and classification will be presented, as well as support vector machines in classification. Further, the toolbox of neural networks will be detailed with applications in classification problems. Unsupervised learning will be studied on clustering problems. Feature extraction and dimensionality reduction will also be covered. Boosting methods will also be covered. Prerequisite: Grade of B or better in EE 3330, EE 2347, MATH 2326, and MATH 3319.

EE 4362. DIGITAL COMMUNICATIONS. 3 Hours.
Fundamental principles underlying the transmission of digital data over noisy channels. Basics of source coding techniques including entropy coding, Lempel-Ziv. Channel capacity. Spectral analysis of digital modulation techniques. Optimum receiver design and error probability performance of commonly used modulation schemes. Applications to lightwave and wireless systems. Prerequisite: Grade of C or better in EE 3318 and in EE 4330.

EE 4364. INFORMATION THEORY FOR DATA SCIENCE. 3 Hours.
Entropy, conditional entropy, relative entropy, mutual information, transfer entropy, entropy rates of stochastic process, data compression, Huffman coding, Shannon coding, compressive sensing, encoding of correlated data, source coding with side information, channel capacity, differential entropy, rate distortion, information theoretical foundations for data science, Bayesian inference, probabilistic reasoning, stock market and portfolio theory. Prerequisite: Must be in the professional EE program and grade C or better in EE 3330.

EE 4375. INTRODUCTION TO POWER ELECTRONICS. 3 Hours.
This course discuses conceptualization, analysis, and design of power electronics components, circuits, and systems. It discusses different classes of switching converters (dc-dc, ac-dc, dc-ac) and elements of power electronics (magnetic design, loads, and capacitors). Applications of power electronics in renewable energy systems and vehicular electronics are discussed. Prerequisite: Grade of C or better in EE 2403 and EE 3446.

EE 4378. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty.

EE 4379. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: EE 4378.

EE 4380. PRINCIPLES OF PHOTONICS AND OPTICAL ENGINEERING. 3 Hours.
Optical fields with applications to laser, optical fibers, and photonic signal processing. Encoding, manipulating, transmitting, storing, and retrieving information using light. Light propagation including isotropic and birefringent optical media, dielectric interfaces, interference and diffraction, Gaussian beams, optical cavities and principles of laser action, optical waveguides and fibers, electro- and acousto-optic modulation. Design, analysis and application of optical devices in communications and signal processing. Prerequisite: Must be in the professional EE program and grade of C or better in EE 3407.

EE 4382. OPTICAL BIOSENSORS. 3 Hours.
Introduction to modern biological and chemical sensing for in-vivo and in-vitro disease diagnosis. Photonics and nanotechnologies for biomolecular analysis. Bio/chemical sensor principle, instrumentation, and applications. Prerequisite: Grade of C or better in EE 3407, or PHYS 3445, or PHYS 4324.

EE 4391. ADVANCED PROBLEMS IN ELECTRICAL ENGINEERING. 3 Hours.
A research project under the direction of a faculty supervisor. May be taken as a technical elective with the permission of the department.

EE 5190. ELECTRICAL ENGINEERING GRADUATE SEMINAR. 1 Hour.
Topics vary from semester to semester. May be repeated for credit. Graded F, P. Prerequisite: graduate standing or consent of the department.

EE 5191. ADVANCED STUDY IN ELECTRICAL ENGINEERING. 1 Hour.
Individual research projects in electrical engineering. Prior approval of the EE Graduate Advisor is required for enrollment. A written report is required. Graded F, I, P.

EE 5302. RANDOM SIGNALS AND NOISE. 3 Hours.
Probability, random variables, and stochastic processes in physical systems. Topics include probability space, discrete and continuous random variables, density and conditional density functions, functions of random variables, mean-square estimation, random signals, system response, optimum system design, and Markov processes.

EE 5304. CYBER-PHYSICAL SYSTEMS. 3 Hours.
Cyber-physical system fundamentals; model-based designs; data-driven analytics; co-design techniques of integrated communication, control, and computing components; implementation considerations; and applications, such as internet of things, intelligent transportation, and robot networking. Topics include but are not limited to hybrid systems, stochastic networks, uncertainty quantification, experimental design, data fusion techniques, stochastic optimal control, networking and edge computing, network control, and related software, hardware, and middleware issues.

EE 5305. ANALOG INTEGRATED CIRCUIT DESIGN. 3 Hours.
Analysis and design of basic analog integrated circuits; device physics; single-stage and differential amplifiers; current mirror and biasing technique; feedback and operational amplifier; noise analysis.

EE 5306. ELECTROMAGNETIC THEORY. 3 Hours.
Advanced study of electromagnetic theory, its content, methods, and applications. Topics include theorems in electromagnetic theory, cylindrical and spherical wave functions, waveguides, integral equation methods, scattering and diffraction.

EE 5307. LINEAR SYSTEMS ENGINEERING. 3 Hours.
Topics include state-space description of dynamic systems, analysis and design of linear systems, similarity transformation, state feedback, state observers, and matrix characterization of multivariable systems.

EE 5308. POWER SYSTEM MODELING AND ANALYSIS. 3 Hours.
Fundamental concepts for modeling transmission lines, distribution lines, power system generators, power transformers and power system load. The method of symmetrical components is discussed. Simulation of power systems during normal and abnormal conditions are presented. The philosophy of deregulation regarding separation of power systems into generation, transmission and distribution companies is introduced.

EE 5309. TOPICS IN ELECTRICAL ENGINEERING. 3 Hours.
Material may vary from semester to semester. Topics are selected from current areas of electrical engineering interest. May be repeated when topic changes.

EE 5310. DIGITAL VLSI DESIGN. 3 Hours.
Introduction of VLSI digital circuit design methodology and processing technology. Application of various design software packages for circuit analysis and layout. Design of basic CMOS digital logic circuits. Implementation of digital logic design at the transistor level.

EE 5311. VLSI SIGNAL PROCESSING ARCHITECTURES. 3 Hours.
Design and synthesis of DSP and telecommunication systems using integrated modeling, design, and verification tools. Exploration of high-level architectural transformations that can be used to design families of DSP architectures for a given signal processing algorithm. Prerequisite: EE 5350.

EE 5312. CMOS RFIC DESIGN. 3 Hours.
Basic concept of RF design; CMOS transceiver architectures for wireless communications; low noise amplifiers; mixers; oscillators; phase-locked loops; frequency synthesizer; power amplifier. Prerequisite: EE 5305.

EE 5313. MICROPROCESSOR SYSTEMS. 3 Hours.
Hardware/software development techniques for microprocessors with emphasis on asynchronous and synchronous memory interfaces, optimizing data throughput, and modern bus architectures. Topics include DMA controller design, SDRAM controller design, and real-world interfacing.

EE 5314. EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Hardware/software development techniques for microcontroller systems with an emphasis on hardware-software interactions, programming internal peripherals, interfacing with external sensors and devices, and real-time control applications.

EE 5315. SYSTEM ON CHIP (SOC) DESIGN. 3 Hours.
Programming and implementation of FPGA-based system on chip solutions, including processor subsystems, FPGA fabric, processor to FPGA bridges, and device drivers. Prerequisite: EE 5314.

EE 5316. CMOS MIXED SIGNAL IC DESIGN. 3 Hours.
Design of CMOS mixed signal ICs with emphasis on full custom chip design. Comparators, switched-capacitor circuits, converter architectures, analog-to-digital converters, digital-to-analog converters, integrator-based filters. A project is required, including design, simulation and layout using an IC design tool. Prerequisite: EE 5305 or EE 5318.

EE 5317. ADVANCED DIGITAL VLSI DESIGN. 3 Hours.
Design of logical gates using CMOS technologies; static and dynamic circuit techniques; advanced techniques in logic circuits; general VLSI system components design; arithmetic circuits in VLSI; low power design; chip layout strategies. A design project using computer tools is required. Prerequisite: EE 5310.

EE 5319. TOPICS IN DIGITAL SYSTEMS. 3 Hours.
Formal instruction in selected topics in digital systems and microcomputers. May be repeated when topic changes.

EE 5321. OPTIMAL CONTROL. 3 Hours.
Design of optimal control systems. Topics include optimization under constraints, linear quadratic regulators, Riccati's equation, suboptimal control, dynamic programming, calculus of variations, and Pontryagin's minimum principle. A prior introductory systems course, such as EE 5307, is desirable.

EE 5322. INTELLIGENT CONTROL SYSTEMS. 3 Hours.
Principles of intelligent control including adaptive, learning, and self-organizing systems. Neural networks and fuzzy logic systems for feedback control. Mobile robots. Discrete event systems and decision-making supervisory control systems. Manufacturing work-cell control. Advanced sensor processing including Kalman filtering and sensor fusion. A prior introductory systems course, such as EE 5307, is desirable.

EE 5323. NONLINEAR SYSTEMS. 3 Hours.
Analysis and design of nonlinear systems. A general course in nonlinear systems with examples from multiple engineering and science disciplines. Topics include phase planes, Lyapunov's theory, describing functions, iterative maps, chaos and fractals, and nonlinear optimization methods. A prior introductory systems course, such as EE 5307, is desirable.

EE 5325. ROBOTICS. 3 Hours.
Principles of kinematics, dynamics, and control of robot manipulators and mobile robots. Analysis of dynamical equations and design of robot control systems using modern nonlinear systems techniques. Computer simulation of robotic and mobile robot systems. Path planning, workcell coordination and control. Also listed as ME 5337.

EE 5327. SYSTEM IDENTIFICATION AND ESTIMATION. 3 Hours.
Introduction to parametric and non-parametric modeling and identification and estimation methods for linear and nonlinear systems. Methods covered include linear and non-linear least squares, LTI (linear time-invariant) black-box models, empirical transfer function estimate, state-space and frequency domain model reduction methods, Kalman filtering and self-tuning adaptive control. Introductory systems and signals courses, such as EE 5302 and EE 5307, are desirable.

EE 5329. TOPICS IN SYSTEMS ENGINEERING. 3 Hours.
Formal instruction in selected topics in systems engineering, such as advanced controls, systems performance, manufacturing, graphics subsystems design, stochastic control, decision and information theory, hierarchical or distributed parameter control. May be repeated when topic changes.

EE 5330. DISTRIBUTED DECISION AND CONTROL. 3 Hours.
Topics include cooperative decision and control algorithms for networked teams of dynamical agents on communication graphs. Included are multi-agent local decision protocols that yield global team behavior, synchronization of dynamics including coupled oscillators and chaotic systems, analysis of stability and consensus convergence behaviors, and group decision and adversarial games on graphs. Applications are to engineering systems such as dynamical systems on communications networks, networked teams of autonomous systems and vehicles, and formation flight.

EE 5331. RF SYSTEMS ENGINEERING. 3 Hours.
Topics include design and performance analysis of transmitter and receiver systems for communications and radar, including digital and analog modulators, transmit lineups, power amplifiers and linearization techniques, feedline structures, antennas, RF propagation channels, receiver lineups, and demodulation techniques. Additional topics include frequency planning, noise and interference mitigation, and regulatory and compliance issues.

EE 5332. ANTENNA SYSTEM ANALYSIS. 3 Hours.
Fundamental study of antennas and antenna design techniques. Topics include analysis of wire antennas, aperture antennas, patch antennas, horns and reflector antennas, and selected novel antennas. Antenna synthesis and measurements. Prerequisite: EE 5306.

EE 5333. WAVE PROPAGATION AND SCATTERING. 3 Hours.
Fundamentals of electromagnetic wave propagation and scattering in radar and wireless communications. Propagation over irregular terrain, in built-up areas, and inside buildings. Scattering from objects and area extensive targets. Propagation and scattering modeling and and their applications in wireless communications and remote sensing. Signal statistics. Prerequisites: EE 5302 and EE 5306.

EE 5334. FUNDAMENTALS OF RADAR REMOTE SENSING. 3 Hours.
Active and passive remote sensing systems, platforms for remote sensing, radar equation, interaction of electromagnetic waves with matter, radar cross section, scattering from area extensive targets, surface scattering, volume scattering, radiative transfer theory, radar data collection and analysis, retrieval of target parameters, and subsurface sensing.

EE 5335. FUNDAMENTALS OF RADAR IMAGING. 3 Hours.
Radar system, electromagnetic waves scattering from targets, radar signal and noise, detection and extraction of signal from noise or clutter, range and Doppler profiles, ambiguity function, radar image formation, real aperture radar imaging, SAR imaging, ISAR imaging, and superresolution radar imaging techniques.

EE 5336. FOUNDATIONS OF MEDICAL IMAGING. 3 Hours.
This course introduces the engineering, physics, mathematics, and signal processing methods fundamental to medical image acquisition and processing: X-ray projection, X-ray computed tomography, magnetic resonance imaging, and ultrasound imaging. Brief introduction to optical and infrared imaging and nuclear imaging (SPECT/PET) will be included. Open to graduate students in College of Engineering or College of Science.

EE 5338. COMPUTATIONAL METHODS IN ELECTRICAL ENGINEERING. 3 Hours.
Mathematical and computational methods to analyze physical phenomena in electrical engineering, including Fourier transformation, finite difference method, finite element method, and integral equation method.

EE 5339. TOPICS IN ELECTROMAGNETICS. 3 Hours.
Formal instruction in selected topics in electromagnetics. May be repeated when topic changes.

EE 5340. SEMICONDUCTOR DEVICE THEORY. 3 Hours.
Quantum mechanics applicable to semiconductor theory. Energy band theory, density of states and effective mass theory. Intrinsic and extrinsic semiconductors, equilibrium statistics for electrons and holes. Transport, generation and recombination of excess carriers. Device equations and physics. Theory and performance of p-n and Schottky diodes, bipolar and MOS transistor electronic devices, and optoelectronic devices.

EE 5341. ELECTRONIC MATERIALS: FUNDAMENTALS AND APPLICATIONS. 3 Hours.
Fundamental theory required for the study of electronic materials: waves and particles, quantum mechanics, crystal structures, chemical bonds, and band theory. Materials and properties considered will be metals, semiconductors, and dielectrics including effective mass, doping, and carrier statistics, and electronic, dielectric, magnetic, and optical properties of materials as applied to integrated circuits, wireless communication, optoelectronics, optical communication, and data storage.

EE 5342. SEMICONDUCTOR DEVICE MODELING AND CHARACTERIZATION. 3 Hours.
Device models and characterization procedures for the pn junction and Schottky diodes, the BJT, JFET, MOSFET, HBT, and optical sources and detectors. SPICE derived and higher level circuit simulator models will be presented. Prerequisite: EE 5340 or EE 5341.

EE 5343. SILICON INTEGRATED CIRCUIT FABRICATION TECHNOLOGY. 3 Hours.
Basic integrated circuit fabrication processes: crystal growth (thin film and bulk), thermal oxidation, dopant diffusion/implantation, thin film deposition/etching, and lithography. Introduction to process simulators, such as SUPREM. Fabrication and characterization of resistors, MOS capacitors, junction diodes and MOSFET devices. Prerequisite: Pass the NanoFAB Safety and Clean Room Protocol test.

EE 5344. INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS (MEMS) AND DEVICES. 3 Hours.
Develops the basics for microelectromechanical devices and systems including microsensors, and micromotors, principles of operation, different micromachining techniques, and thin-film technologies as they apply to MEMS.

EE 5345. INTRODUCTION TO BIO-NANOTECHNOLOGY. 3 Hours.
Introduction to the area of bio-nanotechnology. Basics of nanotechnology as applicable to biological and biomedical sensing, therapy and diagnostics. Theory, fabrication, techniques and uses of nano-scale devices and objects in biomedical and biology.

EE 5346. MICROWAVE DEVICES. 3 Hours.
Device physics and applications of microwave semiconductor devices and vacuum tubes. Topics include operation, modeling and characterization of MESFETs and HEMTs, microwave diodes, and microwave vacuum tubes. Prerequisite: EE 5340 and EE 5341.

EE 5348. RADIO-FREQUENCY CIRCUIT DESIGN. 3 Hours.
Design of lumped- and distributed-element radio-frequency circuits; scattering parameters; impedance-matching circuits; transmission line theory and design; low noise amplifiers; power amplifiers; resonant circuits; noise analysis; RF filter design. Prerequisite: EE 5305.

EE 5349. TOPICS IN INTEGRATED CIRCUIT TECHNOLOGY. 3 Hours.
Formal instruction in selected topics in integrated circuit technology. May be repeated when topic changes.

EE 5350. DIGITAL SIGNAL PROCESSING. 3 Hours.
Time and frequency domain analyses of linear time invariant systems. Stability analyses of causal and non-causal systems using the Z-transform. FIR digital filter design. Design of frequency selective IIR digital filters using frequency transformations and the bilinear transform. Design of infinite and finite impulse response filters.

EE 5351. DIGITAL VIDEO CODING. 3 Hours.
Fundamentals, principles, concepts and techniques of data compression such as Huffman, Lempel-Ziv, Arithmetic, Facsimile, Transform, DPCM, VQ, and Hybrid coding and applications in ITU, ISO, and IEC standards related to audio, video, and image compression.

EE 5352. STATISTICAL SIGNAL PROCESSING. 3 Hours.
Estimation of autocorrelations, cross-correlations and power spectral densities. Least squares filter design via Toeplitz recursion and autoregressive modeling. Steepest descent applications in adaptive noise cancellation and signal recovery. Algorithm development using maximum likelihood and minimum mean square error approaches. Lower bounds on estimation error variance. Prerequisites: EE 5350 or equivalent.

EE 5353. NEURAL NETWORKS AND DEEP LEARNING. 3 Hours.
First and second order training algorithms for both shallow and deep neural networks. Initialization lemmas. Approximation of continuous functions and Bayes discriminants using feedforward networks. Structure and training of convolutional networks, and their relationship to conventional pattern recognition systems. Analyses of drop out and mini-batches. Methods for evaluating network performance. Applications in pattern recognition, estimation and forecasting.

EE 5354. MACHINE LEARNING. 3 Hours.
Fundamental principles and techniques on detecting meaning patterns in data. Supervised learning with applications in regression and classification. Kernel methods and nonlinear spaces along with support vector machines in classification and training of neural networks. Clustering techniques in unsupervised learning. Feature extraction and dimensionality reduction. Graphical models and Hidden Markov models for sequential data and latent variables. Advanced boosting methods, recommended systems as well as online and reinforcement learning techniques.

EE 5355. DISCRETE TRANSFORMS AND THEIR APPLICATIONS. 3 Hours.
Principles and properties of discrete transforms such as discrete Fourier, discrete cosine, Walsh-Hadamard, slant, Haar, discrete sine, discrete Hartley, LOT and Wavelet transforms, and their applications in signal and image processing.

EE 5356. DIGITAL IMAGE PROCESSING. 3 Hours.
Digital image processing as applied to image sampling and quantization, image perception, image enhancement, image restoration, image reconstruction from projections, and filtering and image coding.

EE 5357. STATISTICAL PATTERN RECOGNITION. 3 Hours.
Theories of optimal feature extraction for statistical pattern recognition. Feature extraction using transform based methods, convolutional and other block based approaches. The relationships of Bayes discriminants to neural net, nearest neighbor, SVM, and deep classifiers. Sensor fusion in conventional and convolutional systems. Feature selection using transformation and subsetting approaches.

EE 5358. COMPUTER VISION. 3 Hours.
Techniques for the interpretation, analysis, and classification of digital images. Methods for segmentation, feature extraction, object recognition, stereo vision and 3-D modeling. A research project will be assigned.

EE 5359. TOPICS IN SIGNAL PROCESSING. 3 Hours.
Formal instruction in selected topics in signal processing. May be repeated when topic changes.

EE 5360. DATA COMMUNICATIONS ENGINEERING. 3 Hours.
Layered approach to data communications and networking will be presented. Network models such as TCP/IP and OSI will be introduced. Protocols and technologies related to each layer will be studied in depth. For physical layer, analog and digital signaling, modulation, bandwidth, multiplexing as well as line and block coding techniques. For data link layer, various MAC layer protocols involving multiple access, error detection (CRC), wired (Ethernet) versus wireless (Wi-Fi) LANs, switching. For network layer, internet protocol (IP) and routing principle. Underlying technologies learned from this course are applicable to wide range of traditional and current data communication protocols. Performance analysis of well-known protocols using probabilistic model will also be studied.

EE 5362. DIGITAL COMMUNICATIONS. 3 Hours.
The course presents fundamental principles underlying the transmission and reception of digital information, and studies the different parts of a modern digital communication system. Specifically, the course will touch upon different digital modulation schemes, as well as the design and performance analysis of optimum receivers for additive white Gaussian noise (AWGN) channels. Some concepts of information theory and channel coding will also be studied. Further, techniques for carrier and symbol synchronization will be presented. Communication over bandlimited channels will also be explored, and the effects of intersymbol interference (ISI), as well as channel equalization techniques will be considered.

EE 5364. INFORMATION THEORY FOR DATA SCIENCE. 3 Hours.
Entropy, conditional entropy, relative entropy, mutual information, transfer entropy, data compression, Huffman coding, Shannon coding, compressive sensing, encoding of correlated data, source coding with side information, channel capacity, differential entropy, rate distortion, information theoretical foundations for data science, Bayesian inference, probabilistic reasoning, stock market and portfolio theory.

EE 5365. FIBER OPTIC TRANSMISSION SYSTEMS. 3 Hours.
Propagation in optical fibers, characteristics and manufacture of fibers, semiconductor lightwave sources and detectors, optical transmitters and receivers, lightwave transmission systems for wide area and local area networks.

EE 5368. WIRELESS COMMUNICATION AND IoT. 3 Hours.
Fundamental principles of radio system design and propagation. Basics of cellular systems, environment, propagation models, traffic models and spectral capacity. Multiple-access techniques including FDMA (frequency division multiple access), TDMA (time division multiple access), CDMA (code division multiple access). Machine learning for wireless communications. Internet of Things (IoT) system architecture, IoT enabling technologies such as sensors and sensor networks, IoT communication and networking protocols, IoT services and applications. IoT demands, impacts, and implications on sensors technologies, big data management, and future internet design for various IoT use cases, such as smart cities, smart environments, smart homes, etc.

EE 5369. TOPICS IN COMMUNICATIONS. 3 Hours.
Formal instruction in selected topics in communications. May be repeated when topic changes.

EE 5370. ELECTRIC MOTOR DRIVES. 3 Hours.
Fundamentals of electromechanical energy conversion devices and systems; Principles of inductors, transformers, force/torque formulation, and reference frame transformation; induction motors and permanent magnet machines; Inverter topologies and switching strategies; Scalar and vector control methods for machine drive systems.

EE 5371. POWER SYSTEM PLANNING, OPERATION, AND CONTROL IN A DEREGULATED ENVIRONMENT. 3 Hours.
Current market structure and practices are discussed. The issues of system planning, operation, and control in a deregulated environment are addressed. Prerequisite: EE 5308.

EE 5372. CONGESTION MANAGEMENT. 3 Hours.
Phenomena of congestion and transmission pricing are presented. Thermal related congestion, such as power flow, and stability related congestion, such as voltage stability, transient stability, and dynamic stability, are covered. The effects of reactive power are discussed. Reliability and security issues of power transmission systems are presented. Congestion management and congestion relief measures are discussed. Prerequisite: EE 5308.

EE 5373. UNBUNDLING SERVICES OF A DEREGULATED POWER SYSTEM. 3 Hours.
The fundamental operating functions of a deregulated power system are presented. Unbundling of these functions and cost allocations are discussed. Topics of ancillary services, power marketing, price forecasting, and load forecasting are covered. Prerequisite: EE 5308.

EE 5374. POWER SYSTEM PROTECTIVE RELAYING. 3 Hours.
Fundamental understanding of symmetrical components, applications of symmetrical components in system protection, philosophy of power system protection, various protective relay systems, and the special considerations in applying the microprocessor based relays are covered. Experiments utilizing the Power System Simulation Laboratory are required.

EE 5375. POWER SYSTEM DISTRIBUTION. 3 Hours.
The basic functions of a Distribution Company are presented. Load representation, distribution load flow and the philosophy of simulation for a distribution system are discussed in detail.

EE 5376. POWER SYSTEM RELIABILITY IN PLANNING AND OPERATION. 3 Hours.
Loss of Load indices, Loss of Energy indices, Frequency and Duration methods, Interconnected Reliability methods, and Composite Generation and Transmission Reliability methods will be covered.

EE 5377. PROGRAMMABLE LOGIC CONTROLLERS IN INDUSTRIAL AUTOMATION. 3 Hours.
The application of Programmable Logic Controllers (PLC) in industrial automation and energy systems monitoring will be covered. Transducers, Supervisory Control and Data Acquisition (SCADA) systems, and Distributed Control Systems (DCS) will be discussed. Material covered is also applicable to various mechanical and civil engineering fields, thus enrollment of graduate engineering students from other disciplines is welcome. Experiments utilizing the Power System Simulation Laboratory are required.

EE 5378. POWER QUALITY. 3 Hours.
Principles of harmonics and filtering, source of voltage surges and surge protection, causes of voltage sags, flickers, and interruptions, and voltage supporting devices, and utility and end-user strategies for improving power quality are covered.

EE 5379. TOPICS IN POWER SYSTEM ENGINEERING. 3 Hours.
Formal instruction in selected topics in power system engineering. May be repeated when topic changes.

EE 5380. PRINCIPLES OF PHOTONICS AND OPTICAL ENGINEERING. 3 Hours.
Optical fields with applications to laser, optical fibers, and photonic signal processing. Encoding, manipulating, transmitting, storing, and retrieving information using light. Light propagation including isotropic and birefringent optical media, dielectric interfaces, interference and diffraction, Gaussian beams, optical cavities and principles of laser action, optical waveguides and fibers, electro- and acousto- optic modulation. Design, analysis and application of optical devices in communications and signal processing.

EE 5381. FOUNDATIONS IN SEMICONDUCTORS. 3 Hours.
Electronic properties of semiconductors affecting semiconductor devices: quantum behavior; Kronig-Penny model; energy bands; carrier statistics; density of states; one, two, and three dimensional systems; carrier transport; thermoelectric effects; surface and bulk generation-recombination statistics; continuity equations and their solutions; optical properties; semiconductor characterization techniques.

EE 5382. OPTICAL DETECTORS AND RADIATION. 3 Hours.
Basic principles of optical detectors used in imaging and communications. The course focuses on infrared detectors. Geometric optics, blackbody radiation, radiometry, photon detection mechanisms, thermal detection mechanisms, noise in optical detectors, figures of merit for detectors, photovoltaic detectors, photoconductive detectors, bolometers, pyroelectric detectors, and quantum well detectors.

EE 5383. SOLAR ELECTRICITY & PHOTOVOLTAICS. 3 Hours.
Solar radiation and other forms of renewable energy: wind, tide, biomass and hydropower. Fundamental theory of photovoltaics: crystal structures, band theory, semiconductors, doping, carrier statistics, optical absorption, and p-n junctions. Status of solar cell, including cost, optical design, system engineering, silicon solar cells and thin film solar cells. Prospects of solar cells, regarding low-cost and high-efficiency solar cells. Prerequisite: EE 5340 or EE 5341.

EE 5384. OPTOELECTRONIC DEVICES FOR COMMUNICATION. 3 Hours.
Electronic and optical processes in semiconductors. Light emitting diodes. Laser diodes: structures, properties and operating principles. Photodetectors and solar cells. Noise and the photoreceiver. Optoelectronic modulators and switching devices. Systems needs and new device challenges.

EE 5385. NONLINEAR OPTICS. 3 Hours.
Nonlinear optical processes and applications in crystals, optical fibers and waveguides. Second- and third- order nonlinear susceptibility, symmetry properties, coupled-wave propagation,phase-matching techniques, sum- and difference-frequency generation, parametric amplification, four-wave mixing, self- and cross-phase modulation, soliton propagation, and Raman scattering.

EE 5386. INTEGRATED OPTICS. 3 Hours.
Theory and techniques of integrated optics including optical waveguiding, coupling, modulation, grating diffraction, detection and integrated systems.

EE 5387. FOURIER OPTICS AND HOLOGRAPHY. 3 Hours.
Theory of Fourier optics and holography including scalar diffraction theory, Fresnel and Fraunhofer diffraction, Fourier transforming properties of lenses, optical imaging systems, spatial filtering, and the theory and applications of holography. Prerequisite: EE 5306.

EE 5388. LASERS. 3 Hours.
Propagation of optical rays and waves, Gaussian laser beams, laser resonators, atomic systems, lasing and population inversion, laser amplifiers, practical gas and solid-state lasers including continuous-wave and pulsed lasers, mode locking, Q-switching, frequency doubling, tunable lasers, semiconductor lasers, vertical-cavity lasers and applications of lasers.

EE 5389. TOPICS IN OPTICS. 3 Hours.
Formal instruction in selected topics in optics. May be repeated when topic changes.

EE 5391. ADVANCED STUDY IN ELECTRICAL ENGINEERING. 3 Hours.
Individual research projects in electrical engineering. Prior approval of the EE Graduate Advisor is required for enrollment. A written report is required. Graded F,P,R.

EE 5392. PROJECT IN ELECTRICAL ENGINEERING. 3 Hours.
Individual research projects performed for fulfilling the requirements of the thesis substitute option. Prior approval of the EE graduate advisor is required for enrollment. A written and oral report is required. Graded F, P, R.

EE 5398. THESIS. 3 Hours.
Graded F, P, R. Prerequisite: Graduate standing in electrical engineering.

EE 5698. THESIS. 6 Hours.
Graded F, P, R. Prerequisite: Graduate standing in electrical engineering.

EE 6313. ADVANCED MICROPROCESSOR SYSTEMS. 3 Hours.
Study of the advanced microprocessor architectures including 32/64-bit RISC and CISC families of microprocessors will be compared based on detailed architectural analysis of the selected devices. Topics include: address/instruction pipelines, burst cycles, memory caching and cache coherency issues, register renaming, speculative instruction execution and other performance-oriented techniques. Prerequisite: EE 5313.

EE 6314. ADVANCED EMBEDDED MICROCONTROLLER SYSTEMS. 3 Hours.
Study of advanced microcontroller system designs with an emphasis on multi-tasking, real-time control of devices. Topics include: design of real-time control systems, design of bootloaders, USB peripherals, and Ethernet applications. Prerequisite: EE 5314.

EE 6321. INTRODUCTION TO UNMANNED VEHICLE SYSTEMS. 3 Hours.
Introduction to UVS (Unmanned Vehicle Systems) such as UAS (Unmanned Aircraft Systems), UGS (Unmanned Ground System) and UMS (Unmanned Maritime System), their history, missions, capabilities, types, configurations, subsystems, and the disciplines needed for UVS development and operation. UVS missions could include student competitions sponsored by various technical organizations. This course is team-taught by engineering faculty.

EE 6322. UNMANNED VEHICLE SYSTEM DEVELOPMENT. 3 Hours.
Introduction to the technologies needed to create an UVS (Unmanned Vehicle System). Integration of these technologies (embodied as a set of sensors, actuators, computing and mobility platform sub-systems) into a functioning UVS through team work. UVS could be designed to compete in a student competition sponsored by various technical organizations or to support a specific mission or function defined by the instructors. This course is team-taught by engineering faculty. Prerequisite: EE 6321.

EE 6342. ADVANCED QUANTUM DEVICES. 3 Hours.
Advanced concepts in quantum theory of semiconductors. Epitaxial growth and characterization of heterostructures, quantum wells, and superlattices including strained layers; electronic and optical properties of these structures; electronic and optoelectronic devices based on quantum wells and superlattices. Prerequisite: Graduate standing.

EE 6343. QUANTUM WELL LASERS. 3 Hours.
Introduction to semiconductor heterostructures and quantum wells. Quantum theory of optical processes and laser operation. Threshold, spectral, and dynamical behavior. Modern laser structures and technologies, including strained-layer and surface emitting lasers. Prerequisite: EE 5340 and EE 5341.

EE 6344. NANOSYSTEMS AND QUANTUM ELECTRONIC DEVICES. 3 Hours.
Design, analysis, and techniques for conceptualizing and fabricating nanoscale systems. Role of quantum confinement and mesoscopic behavior, phase coherence, quantum transport, single electron devices, semiconductor heterostructures, self-assembly and molecular electronic schemes, lithographic methods, atomic epitaxy, and surface analysis techniques. Prerequisite: EE 5340 and EE 5341.

EE 6345. ADVANCED MEMS -- MICROELECTROMECHANICAL SYSTEMS. 3 Hours.
Microelectromechanical systems (MEMS) and devices including micro-actuators and optical MEMS. Application strategy of MEMS; fabrication and design; actuation mechanism and architectures; optical sensor and communication applications. Mask layout and hands-on design, fabrication procedures, design rules, demonstrated examples, and integration architectures. Prerequisite: EE 5344.

EE 6353. CONVEX OPTIMIZATION FOR ENGINEERS. 3 Hours.
This course presents an overview of standard methods in convex optimization with applications to real-world problems from multiple areas of engineering and sciences including, signal processing, machine learning, control, networks, power system analysis, mechanical and aerospace, and circuit design. Course materials include advanced linear algebra, numerical algorithms, constrained and unconstrained optimization, duality theory, semidefinite programming, nonlinear and mixed-integer optimization, convex algebraic geometry, and several engineering applications.

EE 6356. IMAGE AND VIDEO CODING. 3 Hours.
Fundamentals, principles, concepts, and techniques of data (image/video/audio) compression such as Huffman coding, arithmetic coding, Lempel-Ziv coding, facsimile coding, scalar and vector quantization, DPCM, PCM, sub-band coding, transform coding, hybrid coding and their applications. Prerequisite: EE 5350.

EE 6364. ADVANCED DATA NETWORKS. 3 Hours.
Network performance analysis, link and upper layer. Internet and ATM protocols, Internet routing and traffic management, ATM switch design and ATM traffic management. Prerequisite: EE 5360.

EE 6365. ADVANCED FIBER OPTICS SYSTEMS. 3 Hours.
Course reviews the modern WDM systems and methods of their design. Topics include architecture of state-of-the-art WDM systems; design of optical amplifiers; signal-to-noise-ratio budget; estimation of various system impairments; popular modulation formats; transmitter and receiver design issues; balancing optical nonlinearity and dispersion; optical networking; and characterization of WDM system's performance. Familiarity with fiber optics and telecommunications is desirable.

EE 6367. ADVANCED AND NEXT-G WIRELESS COMMUNICATIONS. 3 Hours.
Performance analysis of wireless communication systems with multiple input multiple output (MIMO). Space time coding design criteria, space time trellis codes, space time block codes. The next-G wireless communications including mm-wave communications, advanced channel coding, BCJR decoding, Turbo codes, Polar codes, and selected topics in Next-G wireless communications.

EE 6373. RENEWABLE ENERGY SYSTEMS. 3 Hours.
Wind energy harvest, solar energy sources and harvesting, hydropower resources, geothermal, fuel cell and hydrogen economy, power grid interface and distributed generation, microscopic energy harvest from vibration and thermal, role of power electronics in integration of renewable energy systems. Familiarity with the principles of power electronics and electric power recommended.

EE 6375. POWER ELECTRONICS ENGINEERING. 3 Hours.
The course presents selected topics in modeling and analysis of power electronics devices and systems, including dc-dc and dc-ac converters, studies different converter topologies, and investigates various control techniques. The course content helps graduate students to develop and/or improve their research skills in power and energy systems.

EE 6381. NANOPHOTONICS. 3 Hours.
Introduction to nanophotonic materials, devices, systems integration, and applications. Principles of nanoscale structures, quantum dots, photonic crystals, near field optics, plasmonics and metamaterials. Design, modeling, synthesis and fabrication of nano-structures and devices. Scaling of photonic components and optoelectronic integration.

EE 6382. OPTICAL BIOSENSORS: INSTRUMENTATION AND TECHNIQUES. 3 Hours.
Introduction to modern biological and chemical sensing for in-vivo and in-vitro disease diagnosis. Photonics and nanotechnologies for biomolecular analysis. Bio/chemical sensor principle, instrumentation, and applications.

EE 6397. RESEARCH IN ELECTRICAL ENGINEERING. 3 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6399. DISSERTATION. 3 Hours.
Graded F, R.

EE 6697. RESEARCH IN ELECTRICAL ENGINEERING. 6 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6699. DISSERTATION. 6 Hours.
Graded F, R, P, W.

EE 6997. RESEARCH IN ELECTRICAL ENGINEERING. 9 Hours.
Individually approved research projects leading to a doctoral dissertation in the area of electrical engineering. Graded F, P, R.

EE 6999. DISSERTATION. 9 Hours.
Graded F, P, R.

EE 7399. DOCTORAL DEGREE COMPLETION. 3 Hours.
This course may be taken during the semester in which a student expects to complete all requirements for the doctoral degree and graduate. Enrolling in this course meets minimum enrollment requirements for graduation, for holding fellowships awarded by The Office of Graduate Studies and for full-time GTA or GRA positions. Students should verify that enrollment in this course meets other applicable enrollment requirements. To remain eligible in their final semester of study for grants, loans or other forms of financial aid administered by the Financial Aid Office must enroll in a minimum of 5 hours as required by the Office of Financial Aid. Other funding sources may also require more than 3-hours of enrollment. Additional hours may also be required to meet to requirements set by immigration law or by the policies of the student's degree program. Students should contact the Financial Aid Office, other sources of funding, Office of International Education and/or their graduate advisor to verify enrollment requirements before registering for this course. This course may only be taken once and may not be repeated. Students who do not complete all graduation requirements while enrolled in this course must enroll in a minimum of 6 dissertation hours (6699 or 6999) in their graduation term. Graded P/F/R.