Electrical & Systems Engineering

Phone:	314-935-5565
Website:	https://ese.wustl.edu/academics/undergraduate-programs/index.html

Courses

ESE 1050 Introduction to Electrical and Systems Engineering
This course will offer students a rigorous introduction to fundamental mathematical underpinnings of ESE and their relationship to a number of contemporary application areas. Major emphasis will be placed on linear algebra and associated numerical methods, including the use of MATLAB. Topics covered will include vector spaces, linear transformations, matrix manipulations and eigenvalue decomposition. Students will learn how this mathematical theory is enacted in ESE through the completion of four case studies spanning application areas: (i) Dynamical Systems and Control, (ii) Imaging, (iii) Signal Processing, and (iv) Circuits.
Credit 4 units.
Typical periods offered: Fall

ESE 2050 Introduction to Engineering Design
This is a hands-on course in which students, in groups of two or three, will creatively develop projects and solve problems throughout the semester using tools from electrical and systems engineering. Groups will work under the supervision of an academic team consisting of faculty and higher-level students. Project objectives will be set by the academic team in collaboration with each student group. Evaluation will consider completion of these objectives as well as the originality and innovation of the projects. A weekly 90-minute lab with the academic team is required. Prerequisites: CSE 131, Physics 197, or equivalent. Corequisite Course(s): ESE 105, Phy192
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 2170 Differential Equations and Dynamical Systems Modeling in Engineering
This course will provide students with an introduction to differential equations in the context of electrical and systems engineering. Students will gain a foundation in the use of differential equations to describe, model and engineer systems and devices. The course will cover fundamental mathematical principles of ordinary differential equations including: (i) existence of solutions, (ii) elementary solution strategies, and (iii) the conceptual foundation for frequency domain solution techniques. An introduction to early concepts in dynamical systems theory, such as state-space analysis, equilibria and stability, will also be provided. Finally, students will obtain an initial introduction to partial differential equations in ESE in the context of wave propagation. Mathematical developments will be closely accompanied by computational implementations and numerical simulations. Further, students will engage several case studies, in which students will use the mathematical theory to perform analysis and design within ESE contexts spanning systems, circuits and applied physics.
Credit 3 units.
Typical periods offered: Spring

ESE 2180 Linear Algebra and Component Analysis
Linear algebra is the foundation of scientific computing across many disciplines of engineering. This course will introduce the numerical and computational issues that arise from solving large-scale problems, with motivation from data science, machine learning, and signal processing. Topics to be covered include least-squares problems, eigenvalue/eigenvector analysis, singular value decomposition, component analysis, rotation of bases, and concepts of computational complexity and numerical stability. A focus of the class will be studying concepts from signal processing and machine learning such as K-means, Fourier analysis, wavelet analysis, and sampling within the framework of linear algebra. The course will include case studies touching on a broad range of topics including systems science, signals and imaging, devices and circuits, and quantum science/applied physics.
Credit 3 units.
Typical periods offered: Fall

ESE 2190 Vector Calculus and Dynamics of Physical Systems
This course will explore fundamental concepts in vector calculus and partial differential equations with a focus on their practical applications and conceptual understanding. We will derive the Laplace, diffusion, and wave equations and explore their solutions in different coordinate systems. The course will emphasize computational solutions and data visualization in case studies involving applications to areas such as electrostatics, heat conduction in solids , transmission lines, antennas, and wave propagation, providing hands-on experience in solving partial differential equations in real-world scenarios.
Credit 3 units.
Typical periods offered: Spring

ESE 2300 Introduction to Electrical and Electronic Circuits
Electrical energy, current, voltage, and circuit elements. Resistors, Ohm's Law, power and energy, magnetic fields and DC motors. Circuit analysis and Kirchhoff's voltage and current laws. Thevenin and Norton transformations and the superposition theorem. Measuring current, voltage and power using ammeters and voltmeters. Energy and maximum electrical power transfer. Computer simulations of circuits. Reactive circuits, inductors, capacitors, mutual inductance, electrical transformers, energy storage, and energy conservation. RL, RC and RLC circuit transient responses. AC circuits, complex impedance, RMS current and voltage. Electrical signal amplifiers and basic operational amplifier circuits. Inverting, non-inverting, and difference amplifiers. Voltage gain, current gain, input impedance, and output impedance. Weekly laboratory exercises related to the lectures are an essential part of the course.
Credit 4 units.
Typical periods offered: Fall

ESE 2310 Electrical & Electronic Circuits Laboratory
This course covers the lab portion only of E35 230. It is open only to those students who have completed an approved lecture-only circuits course and who need to fulfill the circuits lab requirement for an ESE degree.
Credit 1 unit.
Typical periods offered: Fall

ESE 2320 Introduction to Electronic Circuits
Analysis and design of linear and nonlinear electronic circuits. Detailed analysis of operational amplifier circuits, including non-ideal characteristics. Terminal characteristics of active semiconductor devices. Incremental and DC models for diodes, metal-oxide-semiconductor field effect transistors (MOSFETs), and bipolar junction transistors (BJTs). Design and analysis of single- and multi-stage

amplifiers. Introduction to CMOS logic as well as static and dynamic memory circuits. Students will be required to design, analyze, build and demonstrate several of the circuits studied, including frequency response analysis and use of simulation tools.
Credit 3 units.
Typical periods offered: Spring

ESE 2991 Experience Research in ESE
This course provides students with an initial exposure to research in ESE. This is a mentored experience and requires the agreement of an ESE faculty member to serve in a mentorship role. Students must identify a mentor and obtain their agreement before registering for this course. Activities are to be designed by the student in conjunction with the faculty mentor, and will amount to 2-4 hours of commitment per week. Examples of such activities include, but are not limited to, observation of laboratory experiments, attendance of weekly group meetings, discussions with the mentor, or independent readings. The course is suitable for students at all levels.
Credit 1 unit.
Typical periods offered: Fall, Spring

ESE 2992 Introduction to Research in ESE
This course provides students with an introductory experience with research in ESE. This is a mentored experience and requires the agreement of an ESE faculty member to serve in a mentorship role. Students must identify a mentor and obtain their agreement before registering for this course. Activities are to be designed by the student in conjunction with the faculty mentor, and will amount to 4-6 hours of commitment per week. The research activities will enable the student to gain a deeper understanding of ongoing research related to the mentor's field, or in an area mutually agreed upon by the mentor and the student. The student may also have an opportunity to actively participate in ongoing research activities, such as through assistance of graduate students or postdoctoral associates. Because activities may be unstructured, this course is will require strong time-management skills and self-discipline. The final grade will be determined on the basis of a set of deliverables that are agreed upon by the student and faculty member.
Credit 2 units.
Typical periods offered: Fall, Spring

ESE 3050 Special Topics in Robotics: Practicum in Robotic Systems Design
This is an exciting hands-on course where teams of students (in groups of 4-6) will put a broad range of their engineering skills to use by designing, constructing, and debugging a complex electro-mechanical robotic system. The robotic system will be targeted at some proposed real-world application. Each team will engineer and implement their own solution to the problem. This course is designed to teach students how to apply their theory-based classroom engineering knowledge by exposing students to the design/test/debug/iterate process needed to develop a working integrated system. Some of the topics/skills experienced in the class will include feedback control, real sensor/actuator implementation, circuit design/layout, soldering, asynchronous programming, project management, Design-For-Manufacturability, and more. Students will use the WUSTL Maker Space in this class to learn other valuable hands-on skills (e.g. CAD, CNC machining, 3D printing, laser cutting, etc.).
Credit 3 units.
Typical periods offered: Fall

ESE 3090 Special Topics in Systems Engineering: Modeling and Design of Social Choice Systems
Social choice systems are all around us, from how we decide to split the check to who becomes president. This course introduces many conceptual and computational problems in the study of systems of social choice and offers a variety of tools to understand them. We will consider both micro and macro social choice systems; for the latter drawing on modern statistical techniques to understand (and reframe) questions like what is a fair map of congressional districts? In order to address modeling and design challenges in social choice systems we will explore mathematical and software tools such as game theory, linear optimization, Monte Carlo / MCMC methods, and geographical data representation in Python.
Credit 3 units.
Typical periods offered: Fall

ESE 3260 Probability and Statistics for Engineering
Study of probability and statistics together with engineering applications. Probability and statistics: random variables, distribution functions, density functions, expectations, means, variances, combinatorial probability, geometric probability, normal random variables, joint distribution, independence, correlation, conditional probability, Bayes theorem, the law of large numbers, the central limit theorem. Applications: reliability, quality control, acceptance sampling, linear regression, design and analysis of experiments, estimation, hypothesis testing. Examples are taken from engineering applications.
Credit 3 units.
Typical periods offered: Fall, Spring, Summer

ESE 3300 Engineering Electromagnetics Principles
Electromagnetic theory as applied to electrical engineering: vector calculus; electrostatics and magnetostatics; Maxwell's equations, including Poynting's theorem and boundary conditions; uniform plane-wave propagation; transmission lines, TEM modes, including treatment of general lossless lines, and pulse propagation; introduction to guided waves; introduction to radiation and scattering concepts.
Credit 3 units.
Typical periods offered: Fall

ESE 3301 Electromagnetics Laboratory: Spectrum From Radio to Photonics
Engineering electromagnetics focuses on applying electromagnetic theory to modern technologies including communication, sensing, imaging and medical engineering. This laboratory course provides students with hands-on and practical exposure to the topics covering the electromagnetic spectrum from microwave to optics. Weekly labs will cover topics such as the following: microwave propagation and coupling, transmission line, antenna, RF circuits, basic optoelectronic devices, Fourier optics, light microscopy, holography, light polarization, electro-optics and fiber optics. Students are expected to carry out tests and measurements; analyze, interpret and present experiment data; learn how to perform engineering analysis and design when electromagnetic principles are applied; and gain in-depth understanding of the physics and mathematics underlying the techniques.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 3310 Electronics Laboratory
Laboratory exercises provide students with a combination of hands-on experience involving electronic circuits. Students will use a variety of real instruments, analysis techniques and circuit simulation tools to summarize measurement results in written reports that clearly communicate laboratory results. A sequence of lab experiments

provide hands-on experience in: properties of diodes and transistors, realistic operational amplifier characteristics, grounding and shielding techniques, signal analysis, and op amp based active filter design and characterization. Students will gain experience working with: sampling oscilloscopes to make measurements in the time and frequency domains, signal generators, digital multimeter and frequency measurements, and in creating circuits and making connections on contemporary circuit boards. The course concludes with a hands-on project to design, demonstrate and document the design of an electronic component.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 3320 Power, Energy, and Polyphase Circuits
Fundamental concepts of power and energy; electrical measurements; physical and electrical arrangement of electrical power systems; polyphase circuit theory and calculations; principal elements of electrical systems such as transformers, rotating machines, control, and protective devices, their description and characteristics; elements of industrial power system design.
Credit 3 units.
Typical periods offered: Spring

ESE 3510 Signals and Systems
This course presents an introduction to concepts and methodology of linear dynamic systems in relation to discrete- and continuous-time signals. Topics include mathematical modeling; representation of systems and signals; Fourier, Laplace, and Z-transforms and convolution; input-output description of linear systems, including impulse response and transfer function; time-domain and frequency-domain system analysis, including transient and steady-state responses, system modes, stability, frequency spectra, and frequency responses; and system design, including filter, modulation, and sampling theorem. Continuity is emphasized from analysis to synthesis. MATLAB will be used.
Credit 3 units.
Typical periods offered: Spring

ESE 3590 Signals, Data and Equity
This course introduces the design of classification and estimation systems for equity -- that is, with the goal of reducing the inequities of racism, sexism, xenophobia, ableism, and other systems of oppression. Systems that change the allocation of resources among people can increase inequity due to their inputs, the systems themselves, or how the systems interact in the context in which they are deployed. This course presents background in power and oppression to help predict how new technological and societal systems might interact and when they might confront or reinforce existing power systems. Measurement theory -- the study of the mismatch between a system's intended measure and the data it actually uses -- is covered. Multiple examples of sensing and classification systems that operate on people (e.g., optical, audio, and text sensors) are covered by implementing algorithms and quantifying inequitable outputs.
Credit 3 units.
Typical periods offered: Fall

ESE 4031 Optimization for Engineered Planning, Decisions and Operations
This course will introduce students to the philosophy and skillset of applied optimization with an emphasis on its utility in context. Students will engage with both exact, analytical methods and iterative, numerical methods in a variety of settings, all heavily drawing on MatLab or Python. We will explore linear and integer programming, dynamic programming, the simplex method, network optimization, critical point theory, gradient methods, line search methods, and least squares. Applications include: scheduling, signal denoising, urban planning, portfolio optimization, regression, machine learning.
Credit 3 units.
Typical periods offered: Fall

ESE 4150 Optimization
Optimization problems with and without constraints. The projection theorem. Notions of convexity. Lagrange multipliers and Kuhn-Tucker-type conditions. Duality. Computational methods. Applications of optimization in engineering.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 4170 Introduction to Machine Learning and Pattern Classification
This course provides a broad introduction to machine learning and statistical pattern classification. Students will study theoretical foundations of learning and several important supervised and unsupervised machine learning methods and algorithms, including linear model of regression and classification, logistic regression, Bayesian learning methods, neural networks, nearest neighbor method, support vector machines methods, clustering methods and principal component analysis. Students will also learn to use Python programming language to implement learned models and methods to solve pattern classification problems.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 4250 Random Processes and Kalman Filtering
Probability and random variables; random processes, autocorrelation, power spectral density; transient and steady-state analysis of linear dynamic systems and random inputs, filters, state-space, discretization; optimal estimation; the discrete Kalman filter; linearization and the extended Kalman filter for nonlinear dynamic systems; related MATLAB exercises.
Credit 3 units.
Typical periods offered: Spring

ESE 4261 Statistical Methods for Data Analysis With Applications to Financial Engineering
Introduction to modern methods of statistical data analysis. Data will be used primarily from the financial industry. The course is both computational and mathematical in nature. Most facts will be stated in a rigorous manner, motivated by applications and justified at an intuitive level, but usually not proven rigorously. Emphasis will be on the relevance of concepts and the practical use of tools. A broad range of topics will be covered, including some standard techniques of univariate and multivariate data analysis (histograms, kernel density estimators, Q-Q plots), Monte Carlo simulations and calculations, analysis of heavy tailed data, use of copulas, various parametric and non-parametric regression models, both local and nonlocal, as well as analysis of time series data and Kalman filtering. Methods will be demonstrated on numerous concrete examples, with extensive use of the programming language R.
Credit 3 units.
Typical periods offered: Spring

ESE 4270 Financial Mathematics
This course is a self-contained introduction to financial mathematics at the undergraduate level. Topics to be covered include pricing of the financial instruments such as options, forwards, futures and their derivatives along with basic hedging techniques and portfolio

optimization strategies. The emphasis is put on using of discrete, mostly binary models. The general, continuous case including the concepts of Brownian motion, stochastic integral, and stochastic differential equations, is explained from intuitive and practical point of view. Among major results discussed are the Arbitrage Theorem and Black-Scholes differential equations and their solutions.
Credit 3 units.
Typical periods offered: Fall

ESE 4290 Basic Principles of Quantum Optics and Quantum Information
This course provides an accessible introduction to quantum optics and quantum engineering for undergraduate students. This course covers the following topics: Concept of photons, quantum mechanics for quantum optics, radiative transitions in atoms, lasers, photon statistics (photon counting, Sub-/Super-Poissionian photon statistics, bunching, anti-bunching, theory of photodetection, shot noise), entanglement, squeezed light, atom-photon interactions, cold atoms, atoms in cavities. The course will also provide an overview for quantum information processing: quantum computing, quantum cryptography, and teleportation.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 4301 Quantum Mechanics for Engineers
This course provides an accessible introduction to quantum mechanics and quantum engineering for undergraduate students. Examples are drawn from practical areas of applications of quantum engineering. This course covers the following topics and examples: quantum mechanics and nano-technology, Schrodinger's equation, electron transport in various potential profiles, quantum dots and defects, harmonic oscillator, nano-mechanical oscillator and quantum LC circuit, Stark effect in semiconductors, Bloch theorem, crystal and band structures, Kronig-Penney and tight-binding models, semiclassical and quantum descriptions of light-atom interactions, spontaneous and stimulated emissions, quantum flip-flops, approximate methods in quantum mechanics, spin, quantum gyroscope, spin transistor, and many-particle quantum mechanics for bosons and fermions. Prerequisites: Simple differential equations and matrix algebra at the level of ESE 318/319 Engineering Mathematics A/B or equivalent and familiarity with a modern scientific computing software package (e.g., MATLAB, Mathematica).
Credit 3 units.
Typical periods offered: Fall

ESE 4310 Introduction to Quantum Electronics
Describing the flow of electrical current in nanodevices involves a lot more than just quantum mechanics; it requires an appreciation of some of the most advanced concepts of non-equilibrium statistical mechanics. In the past decades, electronic devices have been shrinking steadily to nanometer dimensions, and quantum transport has accordingly become increasingly important not only to physicists but also to electrical engineers. Traditionally, these topics are spread out over many physics/chemistry/engineering courses that take many semesters to cover. The main goal of this course is to condense the essential concepts into a one-semester course that is accessible to both senior-level undergraduate and junior-level graduate students. This course will be accessible to students with diverse backgrounds in electrical engineering, physics, chemistry, biomedical engineering, and mathematics.
Credit 3 units. Art: NSM
Typical periods offered: Spring

ESE 4330 Radio Frequency and Microwave Technology for Wireless Systems
Focus is on the components and associated techniques employed to implement analog and digital radio frequency (RF) and microwave (MW) transceivers for wireless applications, including: cell phones; pagers; wireless local area networks; global positioning satellite based devices; and RF identification systems. A brief overview of system-level considerations is provided, including modulation and detection approaches for analog and digital systems; multiple-access techniques and wireless standards; and transceiver architectures. Focus is on RF and MW: transmission lines; filter design; active component modeling; matching and biasing networks; amplifier design; and mixer design.
Credit 3 units.
Typical periods offered: Fall

ESE 4340 Solid-State Power Circuits and Applications
Study of the strategies and applications power control using solid-state semiconductor devices. Survey of generic power electronic converters. Applications to power supplies, motor drives, and consumer electronics. Introduction to power diodes, thyristors, and MOSFETs. Prerequisites: ESE 232, 351.
Credit 3 units.
Typical periods offered: Fall

ESE 4350 Electrical Energy Laboratory
Experimental studies of principles important in modern electrical energy systems. Topics include: AC power measurements, electric lighting, photovoltaic cells and arrays, batteries, DC-DC and DC-AC converters, brushed and brushless DC motors and three-phase circuits. Each experiment requires analysis, simulation with MultiSim, and measurement via LabVIEW and the Elvis II platform. Prerequisites: ESE 230 and 351
Credit 3 units.
Typical periods offered: Fall

ESE 4360 Semiconductor Devices
This course covers the fundamentals of semiconductor physics and operation principles of modern solid-state devices such as homo- or hetero-junction diodes, solar cells, inorganic/organic light-emitting diodes, bipolar junction transistors, and metal-oxide-semiconductor field-effect transistors. These devices form the basis for today's semiconductor and integrated circuit industry. In addition to device physics, semiconductor device fabrication processes, new materials, and novel device structures will also be briefly introduced. At the end of this course, students will be able to understand the characteristics, operation, limitations and challenges faced by state-of-the-art semiconductor devices. This course will be particularly useful for students who wish to develop careers in the semiconductor industry.
Credit 3 units.
Typical periods offered: Fall

ESE 4361 Semiconductor Fabrication Lab
This course provides a comprehensive, hands-on introduction to semiconductor processing, focusing on the design, layout, fabrication, and testing of semiconductor devices from start to finish. Throughout the semester, students will learn key techniques and principles in semiconductor device fabrication, including wafer preparation, thermal oxidation, photolithography, doping (activation and diffusion), deposition (CVD, PVD, and ALD), etching (wet and dry), annealing, passivation, and chemical mechanical polishing (CMP). The course highlights the critical role of plasma physics and chemistry in modern semiconductor manufacturing, covering topics such as reactive ion etching (RIE) and plasma-enhanced chemical vapor deposition (PECVD). In addition, students will gain hands-on experience with industry-standard simulation tools used in semiconductor design and

analysis. Through a combination of lectures and weekly lab sessions, students will acquire practical experience in cleanroom environments, mastering the tools and processes required to create functional semiconductor devices. The course culminates in final presentations, where students will share their results and analysis.
Credit 3 units.
Typical periods offered: Spring

ESE 4370 Sustainable Energy Systems
We will survey the field of sustainable energy and explore contributions within electrical and systems engineering. Topics include introductory electric power systems, smart grids, and the roles of heat engines, photovoltaics, wind power, and energy storage, as well as analysis and optimization of energy systems. The course will include review and discussion of literature, problem sets, exams, and student projects. Prerequisites: ESE 318 or 319 and ESE 230 or ESE 351 or permission of instructor.
Credit 3 units.
Typical periods offered: Spring

ESE 4380 Applied Optics
Topics relevant to the engineering and physics of conventional as well as experimental optical systems and applications explored. Items addressed include geometrical optics, Fourier optics such as diffraction and holography, polarization and optical birefringence such as liquid crystals, and nonlinear optical phenomena and devices.
Credit 3 units.
Typical periods offered: Spring

ESE 4390 Introduction to Quantum Communications
This course covers the following topics: quantum optics, single-mode and two-mode quantum systems, nonlinear optics, and quantum systems theory. Specific topics include the following: Dirac notation quantum mechanics; harmonic oscillator quantization; number states, coherent states, and squeezed states; direct, homodyne, and heterodyne detection; linear propagation loss; phase insensitive and phase sensitive amplifiers; entanglement and teleportation; field quantization; quantum photodetection; phase-matched interactions; optical parametric amplifiers; generation of squeezed states, photon-twin beams, non-classical fourth-order interference, and polarization entanglement; optimum binary detection; quantum precision measurements; and quantum cryptography. Prerequisites: ESE 330, or PHY 421; Physics 217 or equivalent.
Credit 3 units.
Typical periods offered: Spring

ESE 4410 Control Systems
Introduction to the theory and practice of automatic control for dynamical systems. Dynamical systems as models for physical and observed phenomena. Mathematical representation of dynamical systems, such as state-space differential and difference equations, transfer functions, and block diagrams. Analysis of the time evolution of a system in response to control inputs, steady-state and transient responses, equilibrium points and their stability. Control via linear state feedback, and estimation using Leunberger observers. Relating the time response of a system to its frequency response, including Bode and Nyquist plots. Input-output stability and its relation to the stability of equilibrium points. Simple frequency-based controllers, such as PID and lead-lag compensators. Exercise involving the use of MATLAB/Simulink (or equivalent) to simulate and analyze systems.
Credit 3 units.
Typical periods offered: Fall

ESE 4440 Sensors and Actuators
The course provide engineering students with basic understanding of two of the main components of any modern electrical or electromechanical system; sensors as inputs and actuators as outputs. The covered topics include transfer functions, frequency responses and feedback control. Component matching and bandwidth issues. Performance specification and analysis, Sensors: analog and digital motion sensors, optical sensors, temperature sensors, magnetic and electromagnetic sensors, acoustic sensors, chemical sensors, radiation sensors, torque, force and tactile sensors. Actuators: stepper motors, DC and AC motors, hydraulic actuators, magnet and electromagnetic actuators, acoustic actuators. Introduction to interfacing methods: bridge circuits, A/D and D/A converters, microcontrollers. This course is useful for those students interested in control engineering, robotics and systems engineering.
Credit 3 units.
Typical periods offered: Fall

ESE 4460 Robotics: Dynamics and Control
Homogeneous coordinates and transformation matrices. Kinematic equations and the inverse kinematic solutions for manipulators, the manipulator Jacobian and the inverse Jacobian. General model for robot arm dynamics, complete dynamic coefficients for six-link manipulator. Synthesis of manipulation control, motion trajectories, control of single- and multiple-link manipulators, linear optimal regulator. Model reference adaptive control, feedback control law for the perturbation equations along a desired motion trajectory. Design of the control system for robotics.
Credit 3 units.
Typical periods offered: Spring

ESE 4480 Control Systems Design Laboratory
This course involves the experimental study of real and simulated systems and their control. Topics covered will include modeling; identification; model validation and control of systems, including noise effects, using a two-link robotic manipulator as an experimental testbed; mathematical modeling of robotic systems; nonlinear and linearized models; input-output and state-space techniques; model validation and simulation; and stabilization using linear and nonlinear control techniques.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 4481 Autonomous Aerial Vehicle Control Laboratory
This course covers the integration of dynamical systems and control engineering principles toward the manipulation of a quadrotor unmanned aerial vehicle (UAV), sometimes referred to as a drone. Students will analytically transform a nonlinear description of the UAV system used for dynamic simulation into a conventional, linear state space system. Students will use key control engineering concepts -- including system identification, state estimation and control synthesis -- to command their UAVs to hover, climb, and orbit. In addition to principles of estimation and identification, students will learn about the theory of guidance and navigation, with projects such as flight planning and execution, collision avoidance, and competitive or cooperative tasks (e.g., formation flight). The overall objective is to expose students to the fusion of control, estimation, and identification techniques that are fundamental to systems theory.
Credit 3 units.
Typical periods offered: Fall, Spring

ESE 4482 Design Challenges in Ese: Modeling and Controlling Human Movement and Choices

The goal of this design-based course is for students to design a system that predicts a human user's motion in a motion capture environment while also influencing their decision-making when presented with multiple choices. The goal is to predict the user's future movement, influence their choice of direction or path, and maximize an objective such as rewards or task completion efficiency. Students will work in teams to complete the task, culminating in a report and presentation. The course is structured as a competition, with a scoring criteria provided as a design specification.
Credit 3 units.

Typical periods offered: Spring

ESE 4590 Special Topics in Cyber-Physical Systems

The industrial internet of things (IIoT) refers to the extension and use of the internet of things (IoT) in industrial sectors and applications. With a strong focus on machine-to-machine (M2M) communication, big data, and machine learning, the IIoT enables industries and enterprises to have better efficiency and reliability in their operations. The IIoT encompasses industrial applications, including robotics, medical devices, and software-defined production processes. This class, through lectures and labs, will cover essentials of IoT hardware and software as well as design thinking as a method of applying empathy and creativity to generate novel solutions to challenging problems in the IIoT space. Students will be presented with a design brief focused on an interactive installation to be placed on campus and will work in groups to develop tiered solutions to the design problem.
Credit 3 units.

Typical periods offered: Fall

ESE 4610 Design Automation for Integrated Circuit Systems

Integrated circuit systems provide the core technology that power today's most advanced devices and electronics: smart phones, wearable devices, autonomous robots, and cars, aerospace or medical electronics. These systems often consist of silicon microchips made up by billions of transistors and contain various components such as microprocessors, DSPs, hardware accelerators, memories, and I/O interfaces, therefore design automation is critical to tackle the design complexity at the system level. The objectives of this course is to 1) introduce transistor-level analysis of basic digital logic circuits; 2) provide a general understanding of hardware description language (HDL) and design automation tools for very large scale integrated (VLSI) systems; 3) expose students to the design automation techniques used in the best-known academic and commercial systems. Topics covered include device and circuits for digital logic circuits, digital IC design flow, logic synthesis, physical design, circuit simulation and optimization, timing analysis, power delivery network analysis. Assignments include homework, mini-projects, term paper and group project.
Credit 3 units.

Typical periods offered: Fall

ESE 4650 Digital Systems Laboratory

Hardware/software co-design; processor interfacing; procedures for reliable digital design, both combinational and sequential; understanding manufacturers' specifications; use of test equipment. Several single-period laboratory exercises, several design projects, and application of microprocessors in digital design.
Credit 3 units.

Typical periods offered: Fall

ESE 4690 Fundamentals of Machine Learning Hardware

This course provides an overview of machine learning algorithms and hardware; inference engines; training engines; emerging hardware architectures; performance analysis; and testing of machine learning accelerators.
Credit 3 units.

Typical periods offered: Fall

ESE 4710 Communications Theory and Systems

Introduction to the concepts of transmission of information via communication channels. Amplitude and angle modulation for the transmission of continuous-time signals. Analog-to-digital conversion and pulse code modulation. Transmission of digital data. Introduction to random signals and noise and their effects on communication. Optimum detection systems in the presence of noise. Elementary information theory. Overview of various communication technologies such as radio, television, telephone networks, data communication, satellites, optical fiber, and cellular radio.
Credit 3 units.

Typical periods offered: Spring

ESE 4740 Introduction to Wireless Sensor Networks

This is an introductory course on wireless sensor networks for senior undergraduate students. The course will use a combination of lecturing and reading and discussion of research papers to help each student to understand the characteristics and operations of various wireless sensor networks. Topics covered include sensor network architecture, communication protocols on Medium Access Control and Routing, sensor network operation systems, sensor data aggregation and dissemination, localization and time synchronization, energy management, and target detection and tracking using acoustic sensor networks.
Credit 3 units.

Typical periods offered: Spring

ESE 4820 Digital Signal Processing

Introduction to analysis and synthesis of discrete-time linear time-invariant (LTI) systems. Discrete-time convolution, discrete-time Fourier transform, z-transform, rational function descriptions of discrete-time LTI systems. Sampling, analog-to-digital conversion, and digital processing of analog signals. Techniques for the design of finite impulse response (FIR) and infinite impulse response (IIR) digital filters. Hardware implementation of digital filters and finite-register effects. The Discrete Fourier Transform and the Fast Fourier Transform (FFT) algorithms.
Credit 3 units.

Typical periods offered: Fall

ESE 4880 Signals and Imaging Laboratory

Hands-on design and analysis that motivates ESE research and courses in signals, communications and imaging. Projects in digital audio signal processing, communication systems, and computational imaging and inverse problems in optics.
Credit 3 units.

Typical periods offered: Fall, Spring

ESE 4970 Electrical Engineering Capstone Design Projects

Capstone design project supervised by the course instructor. The project must use the theory, techniques, and concepts of the student's major: electrical engineering or systems science & engineering. The solution of a real technological or societal problem is carried through completely, starting from the stage of initial specification, proceeding with the application of engineering methods, and terminating with an actual solution. Collaboration with a client, typically either an engineer

or supervisor from local industry or a professor or researcher in university laboratories, is encouraged. A proposal, an interim progress update, and a final report are required, each in the forms of a written document and oral presentation, as well as a Web page on the project. Weekly progress reports and meetings with the instructor are also required. Note: this course will meet at the scheduled time only during select weeks. If you cannot attend at that time, you may still register for the course.
Credit 3 units.

Typical periods offered: Fall, Spring

ESE 4971 Systems Science and Engineering Capstone Design Project

Capstone design project supervised by the course instructor. The project must use the theory, techniques, and concepts of the student's major: electrical engineering or systems science & engineering. The solution of a real technological or societal problem is carried through completely, starting from the stage of initial specification, proceeding with the application of engineering methods, and terminating with an actual solution. Collaboration with a client, typically either an engineer or supervisor from local industry or a professor or researcher in university laboratories, is encouraged. A proposal, an interim progress update, and a final report are required, each in the forms of a written document and oral presentation, as well as a Web page on the project. Weekly progress reports and meetings with the instructor are also required. Note: this course will meet at the scheduled time only during select weeks. If you cannot attend at that time, you may still register for the course.
Credit 3 units.

Typical periods offered: Fall, Spring

ESE 4991 Undergraduate Research

Undergraduate research under the supervision of a faculty member. The scope and depth of the research must be approved by the faculty member prior to enrollment. Final deliverables include a poster presentation at a departmental event, submission of the poster in electronic form for archiving, and written documentation at the discretion of the instructor.
Credit 3 units.

Typical periods offered: Fall, Spring

ESE 4992 Honors Thesis Research

This is the premier research experience for students in ESE, offering a challenging but rewarding opportunity for committed students to work at the cutting edge of engineering research. This is a mentored experience and requires the agreement of an ESE faculty member to serve in a mentorship role. To register for this course, students must obtain the nomination of two faculty members, including their proposed mentor. Nomination must reflect strong academic preparation, interest in research and ability to manage time and work independently. During this course, students will work within their mentor's research group or laboratory to pursue one or more specific research aims. Research is expected to result in a podium presentation and a thesis document that will be archived. Students completing honors thesis will participate in a departmental recognition event.
Credit 4 units.

Typical periods offered: Fall, Spring

ESE 4999 Independent Study

Opportunities to acquire experience outside the classroom setting and to work closely with individual members of the faculty. A final report must be submitted to the department. Not open to first-year or graduate students. Consult adviser. Hours and credit to be arranged.
Credit 3 units.

Typical periods offered: Fall, Spring, Summer