ELECTRICAL ENGINEERING (EE)

Electrical Engineering (EE) Courses

EE 5013. Power System Analysis. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Electric energy and environment, principles of power generation, transmission and distribution, power flow analysis, faults and transient stability analysis, power systems control, and renewable energy systems. This course has Differential Tuition.

EE 5023. Power Electronics. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Switching power converter operation and design; modeling of power converters; power components including power semiconductor devices, inductors, and transformers; control of power converters; and select power converter topology for applications such as renewable energy, electric transportation, and telecommunications. Learning objectives: Analyze the basic operation of switching power converters; simulate the detailed, average, and small-signal operation of power converters; use steady-state, average, and small-signal models of pulse width modulation switch in power converter analysis and design; design of converter power stage for steady-state specifications; and design feedback controller of converters for dynamic specifications. This course has Differential Tuition.

EE 5033. Artificial Intelligence in Power Systems. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Basic principles of AI tools used in electric power systems such as Artificial Neural Networks, Fuzzy Logic, Evolutionary Computing, Genetic Algorithms, Multiagent Systems, and Stochastic Optimization. Application of AI tools in electricity management, fault detection, unit commitment, operation optimization, decision-making, grid control and forecasting, and electricity market operation. It is expected that after successful completion of the class, the student will have the basic knowledge of how to develop systems applied to electric power systems and electricity markets. This course has Differential Tuition.

EE 5053. Advanced Topics in Power and Energy Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 2423, or PHY 1603 and EGR 2323, and graduate standing or consent of instructor. Topics may include the following: 1) Electric Distribution System Modeling and Analysis and Introduction to Distribution Systems. Nature of loads. Series impedance and shunt admittance of overhead and underground lines. Voltage regulation. Three-phase transformer models. Load models. Power flow analysis. Center-tapped transformers and secondaries. Short-circuit studies 2) Nuclear Engineering and Applications; This is an introductory course for graduate students in electrical engineering desiring a nuclear energy sequence and an elective course for students in science and other engineering disciplines. The course aspires to cover the basic knowledge and principles in nuclear energy and engineering and is structured in six parts. (i) Nuclear physics and radiation interactions, (ii) Basics of radiation detection, (iii) Nuclear reactors and nuclear power, (iv) Electric Utility and Nuclear Power Economics, (v) Nuclear Energy, Renewables and Environment, and vi) nuclear instruments and sensors with artificial intelligence applied to nuclear safety, industry and medicine. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5103. Engineering Programming. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Object oriented programming for engineering design problems using C++; software development for mathematical modeling and simulation of hardware systems; extraction and reporting (e.g., text processing) using scripting languages such as Perl; and individual class projects. This course has Differential Tuition.

EE 5113. VLSI System Design. (3-1) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. VLSI Circuit Design, CMOS technology and device modeling, structured digital circuits, VLSI systems; computer-aided design tools, placement, routing, extraction, design rule checking, graphic editors, simulation, verification, minimization, silicon compilation, test pattern generation, theory for design automation, and chip design. (Formerly EE 5323 Topic 1: VLSI I. Credit cannot be earned for both EE 5113 and EE 5323 VLSI I.) This course has Differential Tuition.

EE 5123. Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Description of digital computer systems, arithmetic algorithms, central processor design, memory hierarchies and virtual memory, control unit and microprogramming, input and output, coprocessors, and multiprocessing. This course has Differential Tuition.

EE 5143. Linear Systems and Control. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Advanced methods of analysis and synthesis of linear systems, continuous and discrete-time systems, analytical approach to linear control theory. This course has Differential Tuition.

EE 5153. Random Signals and Noise. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of probability theory, random processes, mean and autocorrelation, stationarity and ergodicity, Gaussian and Markov processes, power spectral density, noise, and linear systems. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5163. Digital Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study of discrete-time signals and systems, including Z-transforms, fast Fourier transforms, and digital filter theory. Filter design and effects of finite register length, and applications to one-dimensional signals. This course has Differential Tuition.

EE 5183. Foundations of Communication Theory. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor, completion of EE 5153 recommended. Basis functions, orthogonalization of signals, vector representation of signals, optimal detection in noise, matched filters, pulse shaping, intersymbol interference, maximum likelihood detection, channel cutoff rates, error probabilities, bandwidth, and power-limited signaling. This course has Differential Tuition.

EE 5193. FPGA and HDL. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamental digital systems principles. HDL modeling concepts and styles: structural, RTL, and behavioral; modeling for synthesis and verification; modeling combinatorial and sequential logic circuits; modeling finite state machines; testbench developments; performance estimation and improvement. (Formerly EE 5223 Topic 2: FPGA and HDL. Credit cannot be earned for both EE 5193 and EE 5223 FPGA and HDL.) This course has Differential Tuition.

EE 5223. Topics in Digital Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor. Topics may include the following: Topic 1: Graph Theory and Networking. Introduction to graphs and digraphs, applications of graphs, Eulerian and Hamiltonian graphs, connectivity, trees, planar graphs, decomposition problems, graph models for electrical and communications networks and computer architectures, communications network application examples, analysis and design. Topic 2: Microcomputer-Based Systems. 8- and 16-bit microprocessors, bus timing analysis, interfacing principles, LSI and VLSI chip interfacing, use of software development tools such as assemblers, compilers, and simulators, and hardware development tools including logic analyzer. Topic 3: PCI System Design. Understanding PCI specifications including protocol, electrical, mechanical, and timing. Study the protocol for high-speed, high-bandwidth data throughput. Designing a PCI-based system design and implementing in FPGA. May be repeated for credit as topics vary. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5243. Special Topics in Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Topics may include the following: Topic 1: Optimal Control. Optimal and suboptimal techniques for controller design using the principle of optimality, min-max principles, and induced norm minimization. Topic 2: Computational Intelligence. A study of neuron models, basic neural nets and parallel distributed processing, and sound mathematical intuition and applications about neural network algorithms and architectures. Includes theory of fuzzy sets, foundations of fuzzy logic, and genetic algorithms. The course emphasizes engineering applications: control, pattern recognition, damage assessment, and decisions. Topic 3: System of Systems Science and Engineering. Introduction to Systems Engineering, Large-Scale Complex Systems, System of Systems (SoS). Architecture and Modeling of System of Systems Engineering, Distributed and Cooperative Control of SoS, discrete-event simulation systems (DEVS) principles and applications, Autonomous Control Systems via Computational Intelligence Tools, principle component analysis and data mining techniques for SoS, V-Lab a Virtual Laboratory and Matlab software for intelligent SoS, case studies: Sensor Networks, System of Robots, Future Combat Systems, Wireless Networks, and System of Energy. Topic 4: Advanced Topics of Embedded Control Systems. Study control techniques for embedded systems. Emphasis on hybrid system configuration, data acquisition, and sensing and fundamentals for motion control systems. Control schemes include NI DAQ-based control and FPGA-based control. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5253. Mathematics for Signal Processing and Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course covers fundamental and advanced linear algebra concepts such as vectors, matrices, factorizations, norms, and least squares. It delves into probability theory and random processes, including joint/conditional probabilities, Bayes' theorem, multivariate distributions, and moments. In the domain of multivariate calculus, gradients and Hessians are explored. Basic optimization topics include convex optimization, KKT conditions, and elements of stochastic optimization. Additional subjects include complex analysis and signal/systems theory, encompassing sampling theory, convolution, filtering, LTI systems, interpolation, and Fourier transform. This course has Differential Tuition.

EE 5263. Advanced Topics in Signal Processing and Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following. Topic 1: Nonlinear Filters. Includes order statistic filters, morphological filters, stack/Boolean filters, and other related topics. Topic 2: Detection and Estimation Theory. Includes minimum-variance unbiased estimation, Cramer-Rao low bound, maximum-likelihood estimation, Bayesian estimation, Neyman-Pearson detector, Bayesian detector, matched filter, and Generalized Likelihood Ratio Test. Topic 3: Orthogonal and Wavelet Transforms with Applications. Includes a broad spectrum of orthogonal transforms, including Cosine, Sine, Hartley, Haar, Slant, Short-time Fourier, Gabor, and Walsh, along with wavelet and sub-band decompositions. Covers the construction, properties, and multiresolution analysis of wavelets and wavelet packets and applications in image and video compression standards, signal and image denoising, steganography, and watermarking. Topic 4: Signal Processing for Wireless Systems. Converse use of transforms for the analysis and design of wireless systems, filter design, and/or adaptive antenna-array processing. Topic 5: Information Theory. Covers concepts like entropy, information content, channel capacity, and the fundamental limits of signal processing and communication systems. Topic 6: Game Theory. Covers mathematical modeling of conflict and cooperation between rational decision-makers, classic games analysis, Nash equilibrium, and the impact of asymmetric information. Includes application examples to real-world scenarios such as wireless communications and AI agents. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5283. Topics in Communications and Intelligent Networks. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics may include the following: Topic 1: Spread Spectrum Communications and GPS. Spread Spectrum (SS) Signals and Systems, Theory of Pseudorandom Sequences, Synchronization (Acquisition, Tracking), CDMA and Global Positioning Systems (GPS, A-GPS, Galileo), Simulations of SS Systems. Topic 2: Simulation of Communication Systems. Simulation and implementation of representative communication systems, Automatic Gain Control (AGC), modulation/demodulation, pulse shaping and matched filters, carrier and time recovery, equalizers, fast correlators. Practical filter design for communication systems. Topic 3: Wireless Communications and Networks. Communication systems, modulation techniques, Spread Spectrum, multiple access techniques, coding, error detection and correction, cellular systems, satellite systems, mobile communications, antennas, networks, TCP/IP suite, network protocols, Mobile IP, Wireless LANs, IEEE 802 standards. Topic 4: 5G Wireless Communications. Concepts, theory, and object oriented modeling of 5G cellular systems in Matlab from the perspective of 3GPP 5G Core Networks (LTE).Coverage includes multi-carrier modulation, OFDMA, fading, multiple antenna systems, diversity, Massive MIMO, millimeter wave communications, adaptive modulation and coding, H-ARQ and system ergodic and outage capacity. 5G Core Networks, Service Based Architectures (SBA), Network Function Virtualization (NFV), Virtualized RAN, Physical Layer Systems, Combined Artificial Intelligence and 5G, and Introduction to 6G. Topic 5: Communication Networks. Introduction and layered network architecture. Point-to-point communication and datalink control (error detection, automatic repeat request protocols, link initialization and disconnect protocols). Delay models in database networks(elements of queueing theory). Multiaccess communication (Aloha, collision resolution protocols, carrier sense multiple access, reservation-based protocols). Routing (packet switching, minimum weight spanning trees, shortest path routing). The Internet Protocol (IP). Transport layer protocols. Flow control. Topic 6: Optimization in Engineering and Data Science. Convex sets and functions. Convex optimization problems: Linear, quadratic, geometric, and semidefinite programming. Optimality conditions. Lagrangian duality. Optimization algorithms: Gradient methods, Newton's method, Lagrange multiplier methods, interior point methods, subgradient methods. Optimization Under Uncertainty and Distributed Optimization. Applications in different areas of Engineering (electric energy systems, control systems, state estimation, optimal network flow for infrastructure systems such as communications, transportation, water), and Data Science (least squares problems, regression models, sparsity/model-selection regularizations, estimation, classification and support vector machines). Topic 7: Computer Network Security. Encryption techniques, symmetric ciphers, public key cryptography, Hash Functions, authentication, email security, IP security, Web security, wireless network security, firewalls. Topic 8: Error Correcting Code. Analysis of error control codes in communication systems, disk drives, satellite communications, and cellular systems, Galois Field Algebra, systematic and non-systematic codes, recursive codes, BCH Codes, Cyclic Codes, Syndrome Decoding, Convolutional Coding and Decoding, Soft Output Viterbi Algorithm (SOVA), Iterative Codes, 5G Error correction Codes, Low Density Parity Check Codes (LDPC), Erasure Codes in data base systems. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5293. Topics in Microelectronics. (3-0) 3 Credit Hours.
Prerequisite: EE 4313. Topics may include the following: Topic 1: Analog Integrated Circuit Design. Introduction to MOS devices and analog circuit modeling. Analog circuits: active resistors, current sources, current mirrors, current amplifiers, inverting amplifier, differential amplifier, cascade amplifier, MOS switches, and the output amplifier. Complex circuits: comparators, operational amplifiers, and other commonly used building blocks for mixed signal systems. Use of CAD tools to layout and simulate analog circuits. Topic 2: Mixed Signal Circuits and Systems. Introduction to the circuits of systems in which analog and mixed signal integrated circuit design are employed. The topics are A/D and D/A converters, including Nyquist-rate and oversampling A/D converters, switched capacitor filters, multipliers, oscillators, the PLL, and circuit design issues, testing, digital calibration and correction. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5323. Topics in VLSI Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5113 or consent of instructor. Topic 1: Advanced VLSI Design. Microelectronic systems architecture; VLSI circuit testing methods; integration of heterogeneous computer-aided design tools; wafer scale integration; advanced high-speed circuit design and integration. Engineering design of large-scale integrated circuits, systems, and applications; study of advanced design techniques, architectures, and CAD methodologies. Topic 2: Low Power VLSI Design. Hierarchy of limits of power, source of power consumption, voltage scaling approaches; circuit, logic, architecture and system level power optimization; power estimation; advanced techniques for power optimization; software design for low power. Topic 3: VLSI Testing. Digital system design verification; logic and fault simulation; testbench guidelines; functional coverage; VLSI manufacturing test; fault modeling; testability measures; Design for Testability (DFT); and Automatic Test Pattern Generation (ATPG). Topic 4: VLSI Performance Analysis and Optimization. Delay models, delay calculation, signal integrity effects, timing analysis, performance variability, performance optimization, and delay test. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5343. Intelligent Control and Robotics. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Study of artificial neural networks control, knowledge-based control, and fuzzy-logic control. Analytical techniques and fundamental principles of robotics; dynamics of robot arms, motion control, robot sensing, and robot intelligence. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 5353. Topics in Multimedia Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 or EE 5163, or consent of instructor. Topics may include the following: Topic 1: Digital Image Processing. Study of binary image processing; histogram and point operations; algebraic and geometric image operations; 2-D digital Fourier transforms; convolution; linear and nonlinear filtering; morphological filters; image enhancement; linear image restoration (deconvolution); digital image coding and compression; and digital image analysis. (Formerly EE 5363. Credit cannot be earned for both EE 5353 Topic 1: Digital Image Processing and EE 5363.) Topic 2: Computer Vision and Application. Image perception, edge detection in the visual system, future vectors, image enhancement, shape from shading, image segmentation by textural perception in humans, chain codes, B-splines, classification (SVM and others). Topic 3: Biomedical Image Processing. This course will examine the fundamental and mathematical aspects of imaging; new algorithms and mathematical tools for the advanced processing of medical and biological images, which include fundamental methods of image reconstruction from their projections, multi-modal imaging, image analysis and visualization, image enhancement, image segmentation and gene-expression calculation, image parameter estimation and measurements, target location, texture synthesis and analysis, morphological image processing, processing of microarray images, processing of FISH stacked images, automated analysis of gene copy numbers by fluorescence in situ hybridization, image acquisition and processing in major imaging techniques, including magnetic resonance, 2-D and 3-D computed tomography, positron emission tomography, and others. Topic 4: Development of Multimedia Applications for Wireless Devices. Programming on wireless systems. Multimedia (image, audio and video) formats. Multimedia processing. Development of sample applications. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5363. Digital Image Processing. (3-0) 3 Credit Hours.
Prerequisites: EE 5153 and EE 5163; or instructor's approval. This course delves into the core techniques of image processing. Topics include binary image processing, histogram and point operations, geometric operations on images, 2-D digital Fourier transforms, Hadamard and cosine transforms, and convolution methods. The curriculum includes both linear and nonlinear filtering, morphological filters, image enhancement, color image processing, and linear image restoration, including deconvolution techniques. It also covers the critical areas of image reconstruction by projections, digital image coding, compression, and detailed image analysis. This course has Differential Tuition.

EE 5373. Wireless Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This course offers an in-depth study of wireless communication systems, propagation modeling for wireless systems, the physical layer and modulation schemes used for wireless channels, diversity techniques, and multiple access schemes used in wireless systems. This course has Differential Tuition.

EE 5403. Advanced Dielectric and Optoelectronic Engineering Laboratory. (2-4) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topic 1: Principles of Dielectric Devices. Evaluation of capacitance devices, impedance frequency and temperature spectrum analysis, characterization of tunable dielectric microwave materials, characterization of piezoelectric devices. Topic 2: Principles of Optical Components and Systems. Lasers, photo-detectors, phase locked interferometer, electro-optical and nonlinear optic devices, optical image processing, Fourier optics, holographic recording, and photorefractive storage. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5413. Principles of Microfabrication. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or completion of EE 3323. Fundamentals of microfabrication techniques, including photolithography, thin film deposition (physical vapor deposition and chemical vapor deposition), etching, thermal oxidation, diffusion, ion implantation, chemical and mechanical polishing, and epitaxy. Nanofabrication techniques that enable sub-micron feature sizes will also be discussed (electron beam or x-ray lithography, focused ion beam, and other bottom-up approaches). Students will visit nearby research institutes and foundry companies as part of this course. (Credit cannot be earned for both EE 4533 and EE 5413. Same as ME 5803. Credit cannot be earned for both EE 5413 and ME 5803.) Generally offered: Fall. This course has Differential Tuition.

EE 5423. Topics in Computer Architecture. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor. Topic 1: Parallel and Distributed Computing. Multiprocessor and multicomputer systems, shared-memory and distributed memory systems, exploitation of parallelism, data partitioning and task scheduling, multiprocessor system interconnects, message passing and data routing, parallel programming. Topic 2: RISC Processor Design, RISC Concept. RISC versus CISC, RISC advantages and disadvantages, various processor survey and applications, study of software development tools: assemblers, compilers, simulators, RISC implementations. Topic 3: Superscalar Microprocessor Architecture. Definition of superscalar, superpipelined, and VLIW processors; available parallelism in programs; branch prediction techniques; memory systems for superscalar processors; trace caches; memory disambiguation and load/store recording; performance evaluation techniques; multimedia extensions in superscalar processors. Topic 4: Fault Tolerance and Reliable System Design. Reliability and availability techniques, maintainability and testing techniques, evaluation criteria, fault-tolerant computing, fault-tolerant multiprocessors, design methodology for high reliability systems. Topic 5: Computer Arithmetic. Fundamental principles of algorithms for performing arithmetic operations in digital computers. Number systems, fast implementations of arithmetic operations and elementary functions, design of arithmetic units using CAD tools. Topic 6: Advanced Computer Architecture. Superscalar and vector processors, advanced pipelining techniques, instruction-level parallelism and dynamic scheduling techniques, advanced memory hierarchy design. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5443. Discrete-Time Control Theory and Design. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Control theory relevant to deterministic and stochastic analysis and design of computer-controlled systems using both state-space and input-output models. This course has Differential Tuition.

EE 5453. Topics in Software Engineering. (3-0) 3 Credit Hours.
Prerequisite: EE 5123 or consent of instructor; concurrent enrollment in QST 6003 is recommended. Topic 1: Large Domain-Specific Software Architectures. Software engineering approaches; scenario-based design processes to analyze large problem domains; domain modeling and representations; creation of component-based architecture providing an object-oriented representation of system requirements; and development of large software class projects. Topic 2: Embedded Software Systems Design. This topic covers dataflow models, uniprocessor and multiprocessor scheduling, hardware/software codesign, hierarchical finite state machines, synchronous languages, reactive systems, and heterogeneous systems. Topic 3: Embedded Software Testing and Quality Assurance. Systematic testing of embedded software systems; unit (module), integration, and system-level testing; software verification; hardware/software cotesting; code inspections; use of metrics; quality assurance; measurement and prediction of software reliability; software maintenance; software reuse and reverse engineering. Topic 4: Advanced Engineering Programming. Programming in the cloud, advanced engineering design problems and techniques using C++ and Java, advanced data structures and complexity analysis of algorithms, dynamic programming using Perl and Python, and large-scale and real-world group and individual projects. Topic 5: Quantum sensing is the most advanced area of quantum information science and engineering, with technological applications currently available on the market. This course will examine spin qubits such as diamond vacancy centers, trapped ions, flux qubits in superconducting circuits, nanoparticles, and photonic quantum systems. Foundational properties and techniques of quantum mechanics, such as perturbation theory, quantum entanglement, quantum interference, and quantum state squeezing, will be covered in depth and used to create sensors with sensitivity and accuracies greater than traditional classical approaches. Quantum sensing of magnetic, electric, gravitational, and broadband electromagnetic fields will be studied, with applications from position, navigation, and timing in GPS-denied environments to the measurement of new space-time scales in the brain via quantum sensor arrays in magnetoencephalography. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5473. Fiber Optic Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. In-depth study of fiber optic principles, performance of optical receivers, devices, digital and analog fiber optic transmission systems, wavelength division multiplexing systems, optical amplifiers, and fiber optic measurements. This course has Differential Tuition.

EE 5503. Introduction to Nanoelectronics. (2-3) 3 Credit Hours.
Prerequisite: Graduate standing or completion of EE 3323. Fundamentals of semiconductor device physics. State-of-the-art CMOS and beyond-CMOS device technologies. Quantum transport theories of electron, phonon, and spin in nanoscale solids. Nanofabrication techniques. Low-dimensional nanomaterials for future electronics. Practical application of nanotechnology in mechanical, optical, and biological heterogeneous systems. Students will study a quantum phenomenon using a device simulation software. (Credit cannot be earned for both EE 4523 and EE 5503. Same as ME 5883. Credit cannot be earned for both EE 5503 and ME 5883.) Generally offered: Spring. This course has Differential Tuition.

EE 5513. Advanced Topics in Image Processing and Computer Vision. (3-0) 3 Credit Hours.
Prerequisite: EE 5153 and EE 5163, or consent of instructor. Topics may include the following: Topic 1: Biomedical Image Processing. The course covers medical and biological image processing, projection-slice theorem, and Radon transform, including image reconstruction by parallel projections, enhancement, and multimodal techniques, along with MRI, CT, and PET imaging applications. Topic 2: Quantum Image Processing. Covering quantum gates and algorithms and their applications in color and grayscale image processing. Students will learn about quantum image representation and processing techniques through a combination of lectures and projects. Topic 3: Computer Vision and Applications. Students explore the core principles of computer vision, from image perception and edge detection to classification with SVMs, applying these concepts to practical domains using tools like chain codes and B-splines. This course has Differential Tuition.

EE 5523. Introduction to Cloud Computing. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Study in concepts related to cloud computing including key components of cloud computing, networking fundamentals, Python programming, resource allocation using cloud APIs, introduction to parallel programming with Python using MPI, data analytics fundamentals such as relational database theory, SQL/noSQL, and Map/Reduce. This course has Differential Tuition.

EE 5543. Non Linear System and Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Nonlinear systems modeling, existence and uniqueness of solutions, phase plane analysis, Lyapunov stability analysis, Lyapunov based nonlinear control techniques. This course has Differential Tuition. Course Fee: L001 $15.

EE 5553. Deep Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153. This course will introduce the basic concept of deep learning and cover most important deep learning models including deep neural networks, convolutional networks, and recurrent neural networks. The course will also cover applications of deep learning in computer vision, natural language processing, computational biology, and other areas. This course has Differential Tuition.

EE 5563. Statistical Inference. (3-0) 3 Credit Hours.
Prerequisite: EE 5153. Fundamentals of hypothesis testing and parameter estimation including likelihood ratio test, unbiased estimation, and minimax estimation. Parametric and nonparametric inference with elements of large sample theory. Graphical models with exact and approximate inference methods including Markov chain Monte Carlo methods and variational inference. Elements of sequential inference including change point detection, hidden-Markov models, and time-series analysis. This course has Differential Tuition.

EE 5573. Machine Learning. (3-0) 3 Credit Hours.
Prerequisite: EE 5153; or instructor's approval. This course introduces the fundamental concepts of machine learning, including supervised, unsupervised, semi-supervised, and reinforcement learning paradigms. It presents both discriminative and generative learning, along with parametric and nonparametric models. The curriculum includes an examination of training, testing, and validation techniques such as cross-validation and statistical methods, including maximum-likelihood and maximum-a-posteriori-probability estimation. Students will have the opportunity to explore various regression models, including linear and non-linear approaches, regularization methods such as ridge and lasso, kernel techniques, logistic regression, classification algorithms, support vector machines, and the perceptron model. The course also focuses on unsupervised learning with a focus on dimensionality reduction, feature selection, and clustering. Potential advanced topics include multi-layer perceptrons, neural networks, stochastic parameter optimization, and backpropagation. The course also includes programming exercises and practical experimentation. This course has Differential Tuition.

EE 5583. Topics in Digital Communication. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Topics may include the following: Topic 1: Digital Information Theory. Entropy and mutual information; Huffman coding; source and channel coding theorems; channel capacity; block coding error bounds; random coding bounds; cutoff rate; multiuser information theory; random access channels and protocols; multiaccess coding methods. Topic 2: Digital Modulation Schemes. In-depth study of digital modulation; information sources and source coding, quantization, representation of digitally modulated signals; synchronization and timing issues in digital communications. Topic 3: Computer Communication Networks. Fundamentals of communication networks, data communication and transmission systems, peer-to-peer protocols, local/wide area networks, multiple access methods, and service integration. Topic 4: Coding and Error Correction. Algebraic Coding Theory; groups and fields, linear codes, Hamming distance, cyclic codes, minimum distance bounds, BACH codes and algebraic decoding, Reed-Solomon codes, Reed-Mueller codes and maximum likelihood decoding, suboptimal decoding, and applications of coding. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5593. Topics in Advanced Sensor Devices. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Fundamentals of materials parameters to design nano-micro level pyroelectric, piezoelectric, ferroelectric and various electronic sensors and actuators. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 5643. Advanced Robotics and Artificial Intelligence. (3-0) 3 Credit Hours.
Introduction and review of manipulator robots, mobile robotics navigation, localization, sensing and control. Drones modeling and control, AI and machine Learning, clustering, PCA, regression, evolutionary computing, fuzzy systems, deep learning, deep neural networks, and projects. This course has Differential Tuition.

EE 5663. Artificial Intelligence. (3-0) 3 Credit Hours.
An introduction to the theories and algorithms used to create artificial intelligence (AI) systems. Topics include search algorithms, logic, probabilistic reasoning, planning, and applications from areas such as computer vision, robotics, and natural language processing. Programming assignments will be provided. This course has Differential Tuition.

EE 5693. Dielectric and Optoelectronic Devices. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Introduction to functional dielectric and optoelectronic materials and devices. Dielectric polarization, relaxation, loss and breakdown properties. Mechanisms of piezoelectric, pyroelectric, and electro-optic properties of solid state materials. This course has Differential Tuition.

EE 5743. Network Multi-agent Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. This course will cover basic network sciences, graph theories, multi-agent system modeling and control, swarms, and social networks. The course will prepare students with fundamental tools to analyze and design network systems with applications in robotics, power systems, social networks, biological networks, and distributed computing and optimization. This course has Differential Tuition.

EE 5763. Applied Natural Language Processing. (3-0) 3 Credit Hours.
Prerequisite: EE 5253; or instructor's approval. This is an interdisciplinary course that introduces students to the design and implementation of Natural Language Processing (NLP) through a project-based approach. Students will learn to design and use NLP methods (such as transformer models and large language models) and creatively apply them to real-world projects, for example, RNA sequence analysis, language translation, text summarization, and security applications. During this course, students have access to state-of-the-art graphics processing units (GPUs) for extensive experimentation. In addition to lectures, the course will invite speakers who are experts in NLP, Machine Learning, and Deep Learning. This course has Differential Tuition.

EE 5843. Optimization and Control of Cyber-Physical Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Modeling of cyber-physical systems; applications in complex urban infrastructure; mathematical optimization; semidefinite programming; dynamic state estimation; robust feedback control; networked control systems; modeling time-delays and cyber-attacks within CPSs; model predictive control. This course has Differential Tuition.

EE 5943. Adaptive Estimation and Control. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Current methods in adaptive systems and control including stability analysis, convergence, robustness, system identification, recursive parameter estimation, and design of parameterized controllers. This course has Differential Tuition.

EE 5993. AI Practicum. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. This AI practicum course includes weekly AI seminar which provides insights on the current state of the AI and ML technologies and covers a wide variety of AI topics, such as computer vision, natural language processing (NLP), theoretical ML, AI fairness & ethics, cognitive science, AI hardware, etc. The seminars will include speakers from industry and academia, who discuss the state of the practice with real use cases and methodologies to make AI projects a tangible success. The practicum also offers an experiential training opportunity to apply AI to problems in the real world. Standard AI programming tool suites and design flow concepts will be learned through the mini-project. Students will also be introduced to how AI is impacting society, the ethics of AI solutions, concerns surrounding AI, and deploying AI in complex scenarios. Python programming experience is needed. This course has Differential Tuition.

EE 6243. Modeling and Control of Three-Phase Pulse-width Modulated Converters. (3-0) 3 Credit Hours.
Prerequisite: Graduate standing or consent of instructor. Develop understanding of power conversion principles in three-phase Pulse-width Modulated (PWM) converters and learn to design the control for the converters used in most applications through: use of switching state vectors and different modulation schemes, development of averaged models of rectifiers and inverters in stationary and rotating coordinates, small-signal modeling in rotating coordinates, and closed loop control design. This course has Differential Tuition.

EE 6343. Advanced Topics in Systems and Control. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the systems and control area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6363. Advanced Topics in Signal Processing. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the signal processing area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6383. Advanced Topics in Communications. (3-0) 3 Credit Hours.
Prerequisite: Consent of Graduate Advisor of Record and Dissertation Director. Current topics in the communications area. May be repeated for credit as topics vary. This course has Differential Tuition.

EE 6493. Advanced Topics in Electronic Materials and Devices. (2-3) 3 Credit Hours.
Prerequisite: EE 5693 and EE 5503 or EE 5593 or consent of instructor. Topics to be selected from advanced sensors, actuators, engineered materials, device physics, microwave applications of MEMS structures, optoelectronics and photonics, microelectronic devices and nanotechnology. May repeated for credit as topics vary. This course has Differential Tuition.

EE 6931. Graduate Research Internship. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6932. Graduate Research Internship. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6933. Graduate Research Internship. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing in electrical and computer engineering and consent of instructor. Research associated with enrollment in the Graduate Research Internship Program. The grade report for the course is either "CR" (satisfactory performance on Graduate Research Internship) or "NC" (unsatisfactory performance on Graduate Research Internship). This course has Differential Tuition.

EE 6941. Graduate Project. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition.

EE 6942. Graduate Project. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition.

EE 6943. Graduate Project. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and Project Advisor. A semester-long project with approval of a supervising faculty. Credit will be awarded upon successful submission of a written report. May be repeated for credit, but not more than 3 hours will apply to the Master's degree. Enrollment is required each term in which the project is in progress. (Formerly EE 6963.) This course has Differential Tuition. Course Fee: DL01 $75.

EE 6951. Independent Study. (0-0) 1 Credit Hour.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6952. Independent Study. (0-0) 2 Credit Hours.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6953. Independent Study. (0-0) 3 Credit Hours.
Prerequisite: Graduate standing and permission in writing (form available) of the instructor and the Graduate Advisor of Record. Independent reading, research, discussion, and/or writing under the direction of a faculty member. For students needing specialized work not normally or not often available as part of the regular course offerings. May be repeated for credit, but not more than 6 hours, regardless of discipline, will apply to the degree. This course has Differential Tuition.

EE 6961. Comprehensive Examination. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record. Independent study course for the purpose of taking the Comprehensive Examination. May be repeated for credit as many times as approved by the Graduate Studies Committee. Enrollment is required each term in which the Comprehensive Examination is taken if no other courses are being taken that term. The grade report for the course is either "CR" (satisfactory performance on the Comprehensive Examination) or "NC" (unsatisfactory performance on the Comprehensive Examination). This course has Differential Tuition.

EE 6973. Special Problems. (3-0) 3 Credit Hours.
Prerequisite: Consent of instructor. An organized course offering the opportunity for specialized study not normally or not often available as part of the regular course offerings. Special Problems courses may be repeated for credit when topics vary, but not more than 6 hours, regardless of discipline, may be applied to the degree. This course has Differential Tuition. Course Fee: LRE1 $25; STSE $30.

EE 6981. Master's Thesis. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6982. Master's Thesis. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6983. Master's Thesis. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Graduate Advisor of Record and thesis director. Thesis research and preparation. May be repeated for credit, but not more than 6 hours will apply to the Master's degree. Credit will be awarded upon completion of the thesis. Enrollment is required each term in which the thesis is in progress. This course has Differential Tuition.

EE 6991. Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). This course may include a written component. May be repeated for credit, but not more than 1 hour will apply to the Master's degree, regardless of discipline. This course has Differential Tuition.

EE 7443. Nonlinear Control Systems. (3-0) 3 Credit Hours.
Prerequisite: EE 5143. Principles of nonlinear systems analysis: Lyapunov stability, input-output stability, and homogeneous system theory. Control of nonlinear systems: integrator backstepping, feedback domination, Lyapunov-based design, small control technique, output feedback design, and applications to physical systems. This course has Differential Tuition.

EE 7931. Doctoral Research Seminar. (1-0) 1 Credit Hour.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7932. Doctoral Research Seminar. (2-0) 2 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7933. Doctoral Research Seminar. (3-0) 3 Credit Hours.
Organized research lectures and seminar presentations. This course may include a written component. The grade report for this course is either "CR" (satisfactory participation in the seminar) or "NC" (unsatisfactory participation in the seminar). May be repeated for credit, but not more than 3 hours will apply to the doctoral degree. This course has Differential Tuition.

EE 7951. Doctoral Research. (0-0) 1 Credit Hour.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7952. Doctoral Research. (0-0) 2 Credit Hours.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7953. Doctoral Research. (0-0) 3 Credit Hours.
Prerequisite: Ph.D. student standing and consent of instructor and the Graduate Advisor of Record. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7991. Doctoral Dissertation. (0-0) 1 Credit Hour.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7992. Doctoral Dissertation. (0-0) 2 Credit Hours.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.

EE 7993. Doctoral Dissertation. (0-0) 3 Credit Hours.
Prerequisite: Consent of the Doctoral Advisor of Record and Dissertation Advisor. May be repeated for a maximum credit of 18 hours. This course has Differential Tuition.