

# ELECTRICAL AND COMPUTER ENGINEERING

## EEE 5225 Resonant MEMS 3 Credits

**Grading Scheme:** Letter Grade

Fundamentals of resonant micro-electro-mechanical systems (Resonant MEMS) and their applications.

**Prerequisite:** Familiarity with ordinary differential equations, elementary signals and systems and circuit theory.

## EEE 5283 Neural Signals, Systems and Technology 3 Credits

**Grading Scheme:** Letter Grade

Biophysical principles of neural signaling, characterization of neural circuits and systems, technology design principles for interfacing with biological neural systems, overview of clinical applications and industrial opportunities for neurotechnology.

**Prerequisite:** Graduate standing in engineering and/or neuroscience or undergraduate senior standing with consent of instructor.

## EEE 5317C Introduction to Power Electronics 3 Credits

**Grading Scheme:** Letter Grade

Components and circuits for power applications. Switched-mode power supplies.

**Prerequisite:** Solid State Devices, Electronic Circuits and Linear Controls. Students may not take this course if they have already taken EEL4242C.

## EEE 5320 Analog IC Design I 3 Credits

**Grading Scheme:** Letter Grade

Amplifier stages, active loads, output stages, op-amps, feedback, frequency response, compensation.

**Prerequisite:** Analog Electronics.

## EEE 5322 VLSI Circuits and Technology 1 3 Credits

**Grading Scheme:** Letter Grade

Introduction to VLSI circuit technology and manufacturing. Fabrication, device models, layout, parasitics, and simple gate circuits.

**Prerequisite:** Electronic Circuits. Students may not take this course if they have already taken EEE 4310.

## EEE 5354L Semiconductor Device Fabrication Laboratory 3 Credits

**Grading Scheme:** Letter Grade

This course will be offering hands-on experience in semiconductor material characterization and device fabrication techniques.

## EEE 5364 Fundamentals of Data Converters 3 Credits

**Grading Scheme:** Letter Grade

Exploring different data conversion techniques with an emphasis on IC implementation. Discussion of circuit building blocks and the effects of their non-idealities in the overall system performance will be analyzed.

**Prerequisite:** Basic Electronic Circuits.

## EEE 5374 Radio Frequency Integrated Circuits 1 3 Credits

**Grading Scheme:** Letter Grade

Teaches RF Electronic circuit design for a modern wireless transceiver and the RF circuit theory necessary to guide good design choices. The students learn to use RF IC design tools to design an RF low noise amplifier IC as part of a team final design project.

**Prerequisite:** Basic Electronic Circuits. Students may not take this course if they have already taken EEE 4373.

## EEE 5379 Introduction to RF Circuits 3 Credits

**Grading Scheme:** Letter Grade

This course is co-listed with the undergraduate class. The homework portion of the graduate section will involve additional work with respect to the undergraduate section. The exams will also involve additional questions or take-home questions for the graduate section with respect to the undergraduate section. Grading for the homework and projects of the graduate section is different from that of the undergraduate course. The graduate and undergraduate sections will be graded separately, for which the graduate section has additional problems and different weights for all problems.

**Prerequisite:** Electromagnetic Fields and Applications and Electronic Circuits or their equivalent.

## EEE 5400 Future of Microelectronics Technology 3 Credits

**Grading Scheme:** Letter Grade

Survey of state-of-the-art microelectronics technology and prospects for future technologies. Nanoscale MOSFETs, strained Si, high-K gate dielectrics, carbon nanotubes, molecular electronics, and single-electron devices.

**Prerequisite:** Solid State Devices. Students may not take this course if they have already taken EEE4329.

## EEE 5405 Microelectronic Fabrication Technologies 3 Credits

**Grading Scheme:** Letter Grade

Principles of microelectronic device fabrication. Emphasis on fundamentals of microfabrication processing and microelectronic device process flows. Computerized process simulation.

**Prerequisite:** Solid State Devices. Students may not take this course if they have already taken EEE4331.

## EEE 5408 Mixed Signal IC Testing I 3 Credits

**Grading Scheme:** Letter Grade

Fundamentals of Testing IC Devices and systems: test specifications, parametric testing, measurement accuracy, test hardware, sampling theory, digital signal processing based testing, and calibrations. Circuit analysis and design with analog and mixed-signal systems. Labs on testing passive components, LDOs, Op-amps, DACS/ADCs, Mixed-Signal ICs Labview and the National Instruments Savage Tester.

**Prerequisite:** Analog and Digital Electronics. Students may not take this course if they have already taken EEE 4404.

## EEE 5415 Modern Memory Device Technologies 3 Credits

**Grading Scheme:** Letter Grade

This course discusses state-of-the-art volatile and nonvolatile memory device technologies and their limitations. It also discusses emerging memory device technologies, including those that could be adopted by industry in the next decades due to their potential performance, density, power and cost advantages.

**Prerequisite:** Solid State Devices.

## EEE 5426 Introduction to Nanodevices 3 Credits

**Grading Scheme:** Letter Grade

Physical principles of modern solid-state devices and their applications; quantum mechanics; fundamentals of nanoelectronics.

**Prerequisite:** Students may not take this course if they have already taken EEE4420.

## EEE 5467 Micro/Nano Machined Metamaterials 3 Credits

**Grading Scheme:** Letter Grade

Study course on the micro-/nano machined metamaterials and their applications for radio frequency (RF) and microwave devices including transmission line, waveguides, resonators, filters, and antennas.

**Prerequisite:** Electromagnetic Fields and Applications

**EEE 5480 Physical Attacks and Inspection of Electronics 3 Credits****Grading Scheme:** Letter Grade

Focuses on the physical inspections, physical attacks, reverse engineering, counterfeit detection, etc. of electronics from the device to system level using advanced microscopy, failure analysis techniques combined with image analysis and machine learning. In addition, students will also learn about the associated countermeasures.

**Prerequisite:** Basic signal processing and circuit analysis knowledge.**EEE 5502 Foundations of Digital Signal Processing 3 Credits****Grading Scheme:** Letter Grade

Analysis and design of digital filters for discrete signal processing, spectral analysis, and fast Fourier transform.

**Prerequisite:** None. Students may not take this course if they have already taken EEL4750.

**EEE 5544 Stochastic Methods for Engineering 1 3 Credits****Grading Scheme:** Letter Grade

Fundamental analytical techniques for modeling, analyzing, and processing electrical signals and computer data in the presence of noise and randomness. Covers from probability to filtering of random processes, with applications to communications, signal and image processing, data compression, and simulation.

**Prerequisite:** Students may not take this course if they have already taken EEL4516.

**EEE 5590 Introduction to Quantum Computing 3 Credits****Grading Scheme:** Letter Grade

Introduces quantum computing concepts and the hardware implementations in a self-contained manner to Electrical and Computer Engineering students. Teaches fundamentals of quantum mechanics and introduces important concepts of superposition and entanglement, hardware realization of quantum computing technologies and quantum computing algorithms.

**Prerequisite:** Solid State Devices and linear algebra or equivalent**EEE 5702 Automated Hardware/Software Verification 3 Credits****Grading Scheme:** Letter Grade

Develop modeling, formal specification, and automated verification skills for analyzing complex hardware and/or software systems. Hands-on experience with model checking tools.

**Prerequisite:** Data Structures, Algorithms and Architecture (Prerequisites allow students to register without departmental intervention. Students are expected to review the syllabus and consult the instructor if they have questions regarding prerequisites).

**EEE 5716 Introduction to Hardware Security and Trust 3 Credits****Grading Scheme:** Letter Grade

Fundamentals of hardware security and trust for integrated circuits. Cryptographic hardware, invasive and non-invasive attacks, side-channel attacks, physically unclonable functions (PUFs), true random number generation (TRNG), watermarking of Intellectual Property (IP) blocks, FPGA security, counterfeit detection, hardware Trojan detection and prevention in IP cores and integrated circuits.

**Prerequisite:** Digital Design. Students may not take this course if they have already taken EEE4714.

**EEE 5725 Acoustics 3 Credits****Grading Scheme:** Letter Grade

Governing equations for wave theory of sound; Character of plane acoustic waves and 3-D acoustic fields; Sound transmission/reflection at an interface between two media; Waves transmission/attenuation inducts; Low frequency approximations (lumped-element modeling) and transducers; sources of sound.

**Prerequisite:** Permission of instructor. Students may not take this course if they have already taken EEE4720.

**EEE 6321 Analog IC Design II 3 Credits****Grading Scheme:** Letter Grade

Design of analog circuits in CMOS IC technology. MOS switches, MOS op amp circuits, circuit simulation using SPICE.

**Prerequisite:** EEE 5320 .**EEE 6323 VLSI Circuits and Technology 2 3 Credits****Grading Scheme:** Letter Grade

Advanced very large scale integrated circuit design, testability, and performance evaluation. Use of industrial VLSI software. Building an advanced CMOS VLSI circuit.

**Prerequisite:** EEE 5322 .**EEE 6328C Microwave IC Design 3 Credits****Grading Scheme:** Letter Grade

Fundamentals of microwave integrated circuit design. Use of computer software to design simple microwave circuits. Microwave circuit testing.

**EEE 6374 RF Circuits and Systems 3 Credits****Grading Scheme:** Letter Grade

Requirements for RF integrated circuits. Design and implementation. Interdependence of RF circuit performance with devices, parasitics, packages, and process technology.

**Prerequisite:** EEE 5322.**EEE 6382 Semiconductor Physical Electronics 3 Credits****Grading Scheme:** Letter Grade

Crystal structure and symmetry, carrier statistics, lattice dynamics, energy band theory, equilibrium properties of semiconductors, recombination-generation and trapping processes, electronic transport phenomena, scattering mechanisms, and optical properties.

**Prerequisite:** EEE 5426.**EEE 6390 VLSI Device Design 3 Credits****Grading Scheme:** Letter Grade

Criteria and tradeoffs in designing high-performance semiconductor devices in scaled (VLSI) Si-based integrated-circuit technologies.

**Prerequisite:** EEE 5426 or EEE 5400.**EEE 6397 Semiconductor Device Theory I 3 Credits****Grading Scheme:** Letter Grade

Semiconductor device physics, equilibrium and non-equilibrium processes, pn junctions, BJT operation, charge-control modeling, and high-current and heavy-doping effects.

**Prerequisite:** EEE 5426.**EEE 6428 Nanoscale Devices for VLSI Technology 3 Credits****Grading Scheme:** Letter Grade

Using nanotechnology simulation tools to study nanoscale devices in future very large scale integration (VLSI) technologies; band structure, transport; molecular transistors, nanowires, nanotransistors, and quantum dots.

**Prerequisite:** EEE 5426.

**EEE 6431 Carbon Nanotubes 3 Credits****Grading Scheme:** Letter Grade

Basic semiconductor and solid-state physics of carbon nanotubes, nanotube geometrical and electronic structure, and current nanotube research.

**Prerequisite:** EEE 5426.**EEE 6460 Advanced Microsystem Technology 3 Credits****Grading Scheme:** Letter Grade

Advanced micro-fabrication technologies, micro-system design, interface circuits, and MEMS packaging. CMOS, Optical, and RF MEMS.

**Prerequisite:** EEL 5225.**EEE 6465 Design of MEMS Transducers 3 Credits****Grading Scheme:** Letter Grade

Design of MEMS transducer systems with physical, technological and economic constraints.

**Prerequisite:** EEL 5225.**EEE 6504 Machine Learning for Time Series 3 Credits****Grading Scheme:** Letter Grade

Theory of adaptation with stationary signals; performance measures. LMS, RLS algorithms. Implementation issues and applications.

**Prerequisite:** EEE 5502 and EEL 5840.**EEE 6512 Image Processing and Computer Vision 3 Credits****Grading Scheme:** Letter Grade

Pictorial data representation; feature encoding; spatial filtering; image enhancement; image segmentation; cluster seeking; two-dimensional z-transforms; scene analysis; picture description language; object recognition; pictorial database; interactive graphics; picture understanding machine.

**Prerequisite:** Digital Signal Processing.**EEE 6545 Stochastic Methods for Engineering 2 3 Credits****Grading Scheme:** Letter Grade

An introduction to stochastic process theory with emphasis on applications to communications, control, signal processing and machine learning. The course covers basic models, including Markov processes, and how they lead to algorithms for classification prediction, inference and model selection.

**Prerequisite:** EEE 5544. Experience with Matlab or Python is essential.**EEE 6586 Automatic Speech Processing 3 Credits****Grading Scheme:** Letter Grade

Various models of speech production and perception. Operation of speech synthesizers. Discussion of speech recognition. Mathematical models of speech signals.

**Prerequisite:** EEE 5502 .**EEE 6742 Advanced Hardware Security and Trust 3 Credits****Grading Scheme:** Letter Grade

Expands on the foundation provided by the Introduction to Hardware Security and highlights the challenges arising from the end of Moore's law as well as the rapid evolution of attackers. Hands-on experience with various commercial and open-source CAD tools will be developed via lectures, tutorials, and projects.

**Prerequisite:** EEE 5716, undergraduate course in digital design, and familiarity with VHDL, Verilog, and CAD/EDA tools.**EEE 6744 Hands-On Hardware Security 3 Credits****Grading Scheme:** Letter Grade

Focuses on practical learning of computer hardware security using a hands-on approach. Students will work on a custom-designed hardware platform to understand innards of a computer system and ethically "hack" into it at different levels. They will examine it to understand security vulnerabilities, mount attacks, and implement countermeasures.

**Prerequisite:** EEE 5716**EEL 5182 State Variable Methods in Linear Systems 3 Credits****Grading Scheme:** Letter Grade

Linear algebra and state variable methods for design and analysis of discrete and continuous linear systems.

**Prerequisite:** Linear Controls. Students may not take this course if they have already taken EEL4610.**EEL 5225 Principles of Micro-Electro-Mechanical Transducers 3 Credits****Grading Scheme:** Letter Grade

Introduction to principles of micro-electro-mechanical devices and systems.

**Prerequisite:** Solid State Devices.**EEL 5249 Fundamentals of RF and Power Electronic Devices 3 Credits****Grading Scheme:** Letter Grade

The course is designed to introduce important semiconductor device technologies for high speed electronics, power electronics and energy harvesting applications.

**Prerequisite:** Solid State Devices.**EEL 5250 Power System Analysis 3 Credits****Grading Scheme:** Letter Grade

Development of power system equivalents by phase, network analysis, load flow, symmetrical components, sequence networks, and fault analysis.

**Prerequisite:** Basic Electric Energy Engineering. Students may not take this course if they have already taken EEL4251.**EEL 5285 Smart Grid for Sustainable Energy 3 Credits****Grading Scheme:** Letter Grade

Survey of power grid operations and markets for students with interest in power systems and/or sustainable energy. Characteristics of traditional and new energy resources; how resources impact the grid; control on many time-scales; how the power grid and power markets of tomorrow will differ from those of today.

**Prerequisite:** Linear Controls and Experience with MATLAB.**EEL 5406 Computational Photography 3 Credits****Grading Scheme:** Letter Grade

Fundamentals of computational photography, sensing, imaging and illumination.

**Prerequisite:** Signals and Systems. Students may not take this course if they have already taken EEL 4403.**EEL 5417 Applied Magnetism & Magnetic Materials 3 Credits****Grading Scheme:** Letter Grade

Introduction to magnetism, magnetic materials, and magnetic devices.

The course offers a balance of theory and application from an applied engineering perspective.

**Prerequisite:** None. Students may not take this course if they have already taken EEL4412.**EEL 5426 RF/Microwave Passive Circuits 3 Credits****Grading Scheme:** Letter Grade

Radio frequency (RF)/microwave passive components and circuits such as transmission lines, waveguides, couplers, filters, and resonators.

**Prerequisite:** Electromagnetic Fields and Applications.

**EEL 5441 Fundamentals of Photonics 3 Credits****Grading Scheme:** Letter Grade

Review of electromagnetic fields and waves, energy bands in semiconductors, p-n junctions and optical properties of semiconductors. Fundamentals of optical modulators and switches, laser theory, laser characteristics, photodetectors, optical waveguides, and photonic applications.

**Prerequisite:** Solid State Devices & Electromagnetic Fields and Applications.

**EEL 5447 Laser Theory and Design 3 Credits****Grading Scheme:** Letter Grade

Studies the field of semiconductor optoelectronics and the physics of optoelectronic devices including the interaction of photons with electrons and holes in a semiconductor leading to the realization of optoelectronic devices such as photon amplifiers, LEDs, diode lasers, electro-absorption modulators, and detectors, including their design and application-specific characteristics.

**Prerequisite:** Physics of Electrical Engineering

**EEL 5462 Advanced Antenna Systems 3 Credits****Grading Scheme:** Letter Grade

Electromagnetic field theory and its application to antenna design.

**Prerequisite:** Electromagnetic Fields. Students may not take this course if they have already taken EEL4461.

**EEL 5486 Electromagnetic Fields and Applications 3 Credits****Grading Scheme:** Letter Grade

Rigorous development of fundamental electrostatic, magnetostatic, and electromagnetic behavior, with special attention toward practical applications. Electrostatics: Gauss' law, electric fields, scalar potential, and energy in simple media. Magnetostatics: Ampère's law, Faraday's law, magnetic fields, vector potential, and energy in simple media.

Electromagnetics: Maxwell's equations, time-varying fields, and Poynting's theorem.

**Prerequisite:** Undergraduate course in fields and waves. Students may not take this course if they have already taken EEL4473.

**EEL 5490 Lightning 3 Credits****Grading Scheme:** Letter Grade

Introduction to lightning discharge processes. Electromagnetics relevant to lightning measurements. Applications for determining lightning charge, current, location, and characteristics. Lightning protection.

**Prerequisite:** Electromagnetic Fields. Students may not take this course if they have already taken EEL4495.

**EEL 5547 Introduction to Radar 3 Credits****Grading Scheme:** Letter Grade

Basic principles of cw and pulsed radar; angle, range, and doppler tracking; accuracy and resolution; signal design.

**Prerequisite:** Wave propagation, noise in communications systems, and Fourier Transforms. Students may not take this course if they have already taken EEL 4540.

**EEL 5632 Safety and Security of Vehicular Electronic Systems 3 Credits****Grading Scheme:** Letter Grade

Provides a comprehensive overview of safety and security of electronic systems in current and emergent vehicles, including automotive and aerospace systems. Topics covered include: vehicular functional safety practices, standards, and limitations; vehicular security and trust; approaches to trustworthy vehicular communications; robustness, resiliency and reliability.

**Prerequisite:** Computer Architecture, Digital Systems Design, and familiarity with C/C++ and Linux.

**EEL 5655 Control of Biological Systems 3 Credits****Grading Scheme:** Letter Grade

The automatic control principles that govern critical processes in human biology are explored. Through the development of mathematical models of biological systems, the course creates an understanding of metabolic, immunologic, and genetic processes. Applications include the manufacture of vaccines, monoclonal antibodies, cancer treatments, insulin, and many others.

**Prerequisite:** Basic knowledge of biology & basic knowledge of control systems.

**EEL 5666C Intelligent Machines Design Laboratory 4 Credits****Grading Scheme:** Letter Grade

Design simulation, fabrication, assembly, and testing of intelligent robotic machines.

**Prerequisite:** EEL 4744C.

**EEL 5718 Computer Communications 3 Credits****Grading Scheme:** Letter Grade

Design of data communication networks: modems, terminals, error control, multiplexing, message switching, and data concentration.

**Prerequisite:** Communication Systems and Components. Students may not take this course if they have already taken EEL4598.

**EEL 5721 Reconfigurable Computing 3 Credits****Grading Scheme:** Letter Grade

Fundamental concepts at introductory graduate level in reconfigurable computing based upon advanced technologies in field-programmable logic devices. Topics include general concepts, device architectures, design tools, metrics and kernels, system architectures, and application case studies.

**Prerequisite:** Digital Design. Students may not take this course if they have already taken EEL4720.

**EEL 5733 Advanced Systems Programming 3 Credits****Grading Scheme:** Letter Grade

Develop a deep understanding of operating system concepts and systems programming fundamentals and gain hands-on experience in systems programming by using Pthreads as well as implementing Linux device drivers and testing/verifying systems code for deadlock and race-freedom.

**Prerequisite:** Operating Systems and Architecture (Prerequisites allow students to register for course without departmental intervention. Students are expected to review the syllabus and consult the instructor if they have questions regarding prerequisites.)

**EEL 5737 Principles of Computer System Design 3 Credits****Grading Scheme:** Letter Grade

This class will be providing a broad introduction to the main principles and abstractions for engineering hardware and software systems, and in-depth studies of their use on computer systems across a variety of designs, be it in operating system, a client/server application, a database server, or a fault-tolerant disk cluster.

**Prerequisite:** Dig. Des. and Comp. Prog.. The project's programming component uses a scripting language (Python) and requires basic understanding of data structures, algorithms, and Unix. Students may not take this course if they have taken EEL 4736.

**EEL 5739 IoT Security and Privacy 3 Credits****Grading Scheme:** Letter Grade

Introduce the advanced topics of IoT security and privacy challenges. Systematically analyze IoT security from hardware, communication, and system perspectives.

**Prerequisite:** Knowledge of microprocessor applications and proficiency in programming in C.

**EEL 5749 IoT Design 3 Credits****Grading Scheme:** Letter Grade

This course focuses on the design of IoT-based solutions for multi-discipline challenges. The course consists of lectures on the fundamental building blocks and protocols in IoT. Then the course will run as a hands-on, multi-discipline project-oriented course, with project discussions, presentations and demonstrations led by student teams.

**Prerequisite:** Graduate-level standing in science or engineering.**EEL 5764 Computer Architecture 3 Credits****Grading Scheme:** Letter Grade

Fundamentals in design and quantitative analysis of modern computer architecture and systems, including instruction set architecture, basic and advanced pipelining, superscalar and VLIW instruction-level parallelism, memory hierarchy, storage, and interconnects.

**Prerequisite:** Digital Design.**EEL 5840 Fundamentals of Machine Learning 3 Credits****Grading Scheme:** Letter Grade

Engineering and hardware concepts pertaining to design of intelligent computer systems.

**Prerequisite:** None; Students may not take this course if they have already taken EEE 4773.

**EEL 5855 Cross Layered Systems Security 3 Credits****Grading Scheme:** Letter Grade

Develop an understanding of the principles of computer security, as it crosses layers of abstraction (application, operating system, hardware and network). Students will learn challenges of building secure computer systems with examples and hands-on assignments. Current research on these challenges will be discussed. Students will review and present conference papers.

**Prerequisite:** Programming knowledge & Principles of computer systems design knowledge

**EEL 5905 Individual Work 1-4 Credits, Max 6 Credits****Grading Scheme:** Letter Grade

Selected problems or projects.

**Prerequisite:** consent of adviser.**EEL 5934 Special Topics in Electrical Engineering 1-3 Credits, Max 18 Credits****Grading Scheme:** Letter Grade

Special Topics in Electrical Engineering

**EEL 6246 Power Electronics II 3 Credits****Grading Scheme:** Letter Grade

Advanced topics including the modeling of single and three-phase power electronics systems, control design for single and three-phase power electronics systems, reduction and modeling of EMI for power electronics systems and resonant power converters.

**Prerequisite:** EEE 5317C or equivalent.**EEL 6275 Power System Protection 3 Credits****Grading Scheme:** Letter Grade

Unbalanced Load Flow; Fault Analysis on Distribution Systems; Multi-machine Stability; Balanced/Unbalanced State Estimation; Principles of Protection, Transducers and Relay Classification; Circuit Breakers; Protection of Distribution and Transmission Lines, Transformers, Generators, Motors/Buses, Reactors/Capacitors, Distributed Generation; Power System Phenomena and Relying Considerations System Performance; Fault Location.

**Prerequisite:** EEL 5250**EEL 6487 Electromagnetic Field Theory and Applications II 3 Credits****Grading Scheme:** Letter Grade

Electromagnetic radiation, antennas, wave propagation in anisotropic media.

**Prerequisite:** EEL 5486.**EEL 6507 Queuing Theory and Data Communications 3 Credits****Grading Scheme:** Letter Grade

Introduction to basic queuing models; performance analysis of multiple access protocols; error control strategies.

**Prerequisite:** EEE 5544.**EEL 6509 Wireless Communication 3 Credits****Grading Scheme:** Letter Grade

Introduction. Satellite and cellular systems, propagation, modulation techniques, multiple access techniques, channel coding, speech and video coding, and wireless computer networks.

**Prerequisite:** Graduate level course in noise in linear systems.**EEL 6528 Digital Communications with Software-defined Radios 3 Credits****Grading Scheme:** Letter Grade

Basics of software-defined radios; Introduction to USRP radios and GNU Radio software platform; Practical communication algorithms and designs; Implementation of communication systems in USRP radios.

**Prerequisite:** EEL 6535 or EEL 6509.**EEL 6532 Information Theory 3 Credits****Grading Scheme:** Letter Grade

Applications of information theory to communications and other related areas.

**Prerequisite:** EEE 5544 or equivalent.**EEL 6533 Data Analytics and Decision Sciences 3 Credits****Grading Scheme:** Letter Grade

Hypothesis testing of signals in the presence of noise by Bayes, Neyman-Pearson, minimax criteria; estimation of signal parameters.

**Prerequisite:** EEE 5544.**EEL 6535 Digital Communications 3 Credits****Grading Scheme:** Letter Grade

Digital modulation techniques; analysis of digital communication systems in presence of noise; optimum principles; synchronization; equalization.

**Prerequisite:** EEE 5544.**EEL 6537 Spectral Sensing and Sparse Signal Recovery 3 Credits****Grading Scheme:** Letter Grade

Measurement and analysis of signals and noise. Digital filtering and spectral analysis; fast Fourier transform.

**Prerequisite:** EEE 5544, EEE 5502 .**EEL 6550 Error Correction Coding 3 Credits****Grading Scheme:** Letter Grade

Introduction to abstract algebra, block coding and decoding, convolutional coding and decoding, trellis coded modulation, and run-length-limited codes.

**Prerequisite:** EEE 5544 or equivalent. ;**Corequisite:** EEE 5544 or 4516.

**EEL 6555 Signal Processing for Active Sensing 3 Credits****Grading Scheme:** Letter Grade

Theoretically developing an active sensing system by taking into account the probing waveform synthesis considerations under various spectrum restrictions, as well as the sophisticated receiver statistical and array signal processing methodologies to combat diverse adverse effects such as interference and jamming.

**Prerequisite:** EEL 6537 or equivalent.**EEL 6588 Wireless Ad Hoc Networks 3 Credits****Grading Scheme:** Letter Grade

Advanced research-oriented course covering various topics relevant to a cutting-edge technology, namely wireless ad hoc networks, mobile ad hoc networks, wireless sensor networks, and/or wireless mesh networks.

**Prerequisite:** EEL 5718, Graduate student standing.**EEL 6591 Wireless Networks 3 Credits****Grading Scheme:** Letter Grade

Design and analysis of wireless networks including channel characteristics, physical layer, cellular concepts, multiple access control protocols, FEC and ARQ protocols, resource allocation, and wireless standards.

**Prerequisite:** EEL 5718 and knowledge of probability and statistics.**EEL 6614 Modern Control Theory 3 Credits****Grading Scheme:** Letter Grade

Optimization of systems using the calculus of variations, dynamic programming, and the maximum principle. Extensive study of the linear plant with a quadratic performance index. Observers and dynamic compensators.

**Prerequisite:** EEL 5182.**EEL 6617 Linear Multivariable Control 3 Credits****Grading Scheme:** Letter Grade

Transfer matrix theory of systems, emphasis on feedback, internal stability, model matching, and assignment of invariant factors.

**Prerequisite:** EEL 5182.**EEL 6686 Embedded Systems Seminar 3 Credits****Grading Scheme:** Letter Grade

An embedded system is any computing system other than traditional computer systems. Examples include set-top boxes, digital cameras, alarm systems, automotive systems, aerospace systems, and cell phones. Structured as a seminar course and will review cutting-edge publications with student presentations.

**Prerequisite:** CDA 5636.**EEL 6706 Fault-Tolerant Computer Architecture 3 Credits****Grading Scheme:** Letter Grade

Design and quantitative analysis of fault-tolerant architectures and dependable systems including fundamental issues, redundancy techniques, evaluation methods, design methodology, and applications.

**Prerequisite:** EEL 5764 or CDA 5155.**EEL 6761 Cloud Computer Systems and Applications 3 Credits****Grading Scheme:** Letter Grade

A broad introduction to cloud and distributed computing, big data platforms and intelligent platforms. It covers system architecture, programming models, algorithmic design, and big data applications. Selected applications will be used as case studies.

**Prerequisite:** EEL 5737 or EEL 5764. Instructor approval possible if student demonstrates familiarity with algorithms, data structure, computer systems, and programming (such as Java, Python, C/C++, Go, Scala).

**EEL 6763 Parallel Computer Architecture 3 Credits****Grading Scheme:** Letter Grade

Advanced architecture emphasizing design and quantitative analysis of parallel architecture and systems, including theory, hardware technologies, parallel and scalable architectures, and software constructs.

**Prerequisite:** EEL 5764.**EEL 6814 Neural Networks and Deep Learning 3 Credits****Grading Scheme:** Letter Grade

Nonlinear modeling and neural networks. Gradient descent learning in the additive neural model; statistical learning concepts; dynamic neural networks, function approximation and short-term memory; unsupervised learning networks; generative models and statistical representation; autonomous learning using cognitive principles. Importance and challenges of deep learning; applications for image, video, speech recognition.

**Prerequisite:** EEL 5840**EEL 6825 Pattern Recognition and Intelligent Systems 3 Credits****Grading Scheme:** Letter Grade

Decision functions; optimum decision criteria; training algorithms; unsupervised learning; feature extraction, data reduction; potential functions; syntactic pattern description; recognition grammars; machine intelligence.

**Prerequisite:** Machine Learning.**EEL 6841 Machine Intelligence and Synthesis 3 Credits****Grading Scheme:** Letter Grade

Theory of machine intelligence applied to general problem of engineering intelligent computer systems and architecture. Applications emphasized.

**Prerequisite:** EEL 5840.**EEL 6871 Cloud Computing Systems Management 3 Credits****Grading Scheme:** Letter Grade

An introduction to models, software platforms, optimization techniques, predictive modeling, feedback-based computing approaches, monitoring techniques and applications of software-defined cloud management.

These concepts are needed to enable the automated management of the scale and service orientation of cloud computing systems.

**Prerequisite:** EEL 5737 or EEL 6892**EEL 6892 Virtual Computers 3 Credits****Grading Scheme:** Letter Grade

Techniques for virtualization of networked computer systems. Virtual machines (classic VMs, application binary interface VMs, para-virtualization), virtual distributed file systems (file system proxies, call-forwarding), and virtual networks (tunneling, virtual private networks).

**Prerequisite:** EEL 5737 or instructor approval.**EEL 6905 Individual Work 1-4 Credits, Max 6 Credits****Grading Scheme:** Letter Grade

Selected problems or projects.

**Prerequisite:** consent of adviser.**EEL 6910 Supervised Research 1-5 Credits, Max 5 Credits****Grading Scheme:** S/U

Supervised Research

**EEL 6933 Electrical and Computer Engineering Graduate Seminar 1 Credit, Max 3 Credits****Grading Scheme:** S/U

Exploring ECE research through presentations by faculty members, graduate students, and invited speakers.

**Prerequisite:** Graduate student status

**EEL 6935 Special Topics in Electrical Engineering 1-4 Credits, Max 12****Credits****Grading Scheme:** Letter Grade

Special Topics in Electrical Engineering

**EEL 6940 Supervised Teaching 1-5 Credits, Max 5 Credits****Grading Scheme:** S/U

Supervised Teaching

**EEL 6971 Research for Master's Thesis 1-15 Credits****Grading Scheme:** S/U

Research for Master's Thesis

**EEL 7979 Advanced Research 1-12 Credits****Grading Scheme:** S/U

Research for doctoral students before admission to candidacy. Designed for students with a master's degree in the field of study or for students who have been accepted for a doctoral program. Not appropriate for students who have been admitted to candidacy.

**EEL 7980 Research for Doctoral Dissertation 1-15 Credits****Grading Scheme:** S/U

Research for Doctoral Dissertation

**EGN 5949 Practicum/Internship/Cooperative Work Experience 1-6****Credits, Max 6 Credits****Grading Scheme:** S/U

Practical cooperative engineering work under approved industrial and faculty supervision.

**Prerequisite:** graduate student.**EGN 6640 Entrepreneurship for Engineers 3 Credits****Grading Scheme:** Letter Grade

Introduction to entrepreneurship, idea generating and feasibility analysis, and business planning. Lectures, case studies, student-led discussions, team business plans, and investor presentations.

**EGN 6913 Engineering Graduate Research 0-3 Credits, Max 12 Credits****Grading Scheme:** S/U

Course will provide the student with supervised research in a laboratory setting.