

# ECE - ELECTRICAL AND COMPUTER ENGINEERING

## **ECE 2050 Object-Oriented Programming for Electrical and Computer Engineering Cr. 3**

Rigorous project-based, object-oriented programming course in C++ for ECE with an overview of computer engineering and systems. Covered topics include: problem-solving principles; object-oriented programming (classes and objects, control statements, functions, pointers, arrays, vectors, inheritance, polymorphism, exception handling, file processing, dynamic memory allocation); software engineering principles; basic data structures and algorithms: linked lists, recursion, sorting, and basic analysis of algorithms. Offered Fall, Winter.

**Prerequisites:** MAT 2010 with a minimum grade of C-

## **ECE 2610 Digital Logic Design Cr. 4**

Topics include: data representation in digital computer; boolean algebra; logic gates; minimization and implementation of boolean functions; arithmetic circuits; combinational circuits; sequential circuits: latches and flip-flops; counters; finite state machines; memories; and Verilog programming. Laboratory experiments provide hands-on experience using state-of-the-art FGA setup to simulate, implement, and test combinational and sequential logic circuits. Offered Every Term.

**Prerequisites:** (CSC 2000 with a minimum grade of C- (may be taken concurrently) or ECE 2050 with a minimum grade of C-) and (PHY 2185 with a minimum grade of C- (may be taken concurrently) or PHY 2180 with a minimum grade of C- (may be taken concurrently))

**Restriction(s):** Enrollment is limited to Undergraduate level students.

**Course Material Fees:** \$10

## **ECE 3040 Numerical Methods for Engineers Cr. 3**

Developing numerical algorithms to provide solutions to engineering problems. Derivation of numerical algorithms and investigation of their stability, accuracy, efficiency and scalability. Programming numerical algorithms in Matlab. Topics include: Machine Round-off error, truncation error, root finding, solution of systems of linear and nonlinear algebraic equations, Taylor and Chebyshev series and rational function approximation, interpolation, regression, numerical differentiation, numerical integration, numerical solution of ordinary differential equations, and Monte Carlo methods. Offered Every Term.

**Prerequisites:** BE 1200 with a minimum grade of C-, BE 1500 with a minimum grade of C-, MAT 2030 with a minimum grade of C-, and (MAT 2150 with a minimum grade of C- (may be taken concurrently) or (MAT 2250 with a minimum grade of C- (may be taken concurrently) and MAT 2350 with a minimum grade of C- (may be taken concurrently)))

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering.

**Course Material Fees:** \$15

## **ECE 3300 Introduction to Electrical Circuits Cr. 4**

Electrical quantities and waveforms; resistance and Ohm's law; networks and Kirchhoff's laws; network equivalents; nodal and mesh analysis; Thevenin's theorem and other network theorems. First- and second-order systems. Offered Every Term.

**Prerequisites:** (PHY 2185 with a minimum grade of C- or PHY 2180 with a minimum grade of C-) and (MAT 2150 with a minimum grade of C- (may be taken concurrently) or (MAT 2250 with a minimum grade of C- (may be taken concurrently) and MAT 2350 with a minimum grade of C- (may be taken concurrently)))

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$25

## **ECE 3320 Introduction to Electrical Circuits Cr. 4**

Electrical signals and waveforms; resistance and Ohm's law; networks and Kirchhoff's laws; network equivalents; nodal and mesh analysis; Thevenin's theorem; energy storage systems; Introduction to sinusoidal steady-state response; complex frequency concepts; Frequency responses. No credit towards B.S. EE degree. Offered Yearly.

**Prerequisites:** (PHY 2185 with a minimum grade of C- or PHY 2180 with a minimum grade of C-) and MAT 2150 with a minimum grade of C- (may be taken concurrently)

## **ECE 3330 Electrical Circuits II Cr. 3**

Sinusoidal steady-state response; three-phase systems; complex frequency concepts; frequency responses; resonant and coupled circuits; application of Fourier transforms and Laplace transform to electrical circuits. Offered Every Term.

**Prerequisites:** (MAT 2150 with a minimum grade of C- or (MAT 2250 with a minimum grade of C- and MAT 2350 with a minimum grade of C-)) and ECE 3300 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

## **ECE 3570 Electronics Cr. 4**

DC and small signal analysis of diodes, MOSFETs, and BJTs circuits; operational amplifiers, single-stage amplifiers, differential pair, gain, input resistance, output resistance, and bandwidth of amplifiers. Offered Every Term.

**Prerequisite:** ECE 3330 (may be taken concurrently) with a minimum grade of C- and ECE 3300 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$15

## **ECE 3620 Introduction to Microcomputers Cr. 4**

Basics of digital systems, number systems, functional blocks of microcomputers, assembly language and machine code, applications of microcomputers and experimental demonstrations. Introduction to digital logic. Offered Every Term.

**Prerequisites:** BE 1200 with a minimum grade of C- and (ECE 2610 with a minimum grade of C- or ECE 3610 with a minimum grade of C-)

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering.

**Course Material Fees:** \$25

**ECE 4050 Algorithms and Data Structures Cr. 3**

Introduction to problem solving methods and algorithm development; data abstraction for structures such as stacks, queues, linked lists, trees, and graphs; searching and sorting algorithms and their analysis. Offered Yearly.

**Prerequisite:** CSC 2000 with a minimum grade of C- and MAT 2860 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4330 Linear Systems and Signals Cr. 4**

Content includes: continuous-time and discrete-time linear systems and signals; properties of linear systems; classical analysis methods and convolution; system analysis method for zero-state and zero-input response; Laplace transform and its application to linear system analysis; Fourier series expansion of periodic signals; Fourier transform and the steady-state response; application to analog filters, control and communication systems; solution of linear difference equations; z-transform analysis method; sampling theory; discrete-time Fourier transform and its application in digital filter design. Offered Every Term.

**Prerequisites:** ECE 3330 with a minimum grade of C- and (ECE 3040 with a minimum grade of C- (may be taken concurrently) or BE 2550 with a minimum grade of C- (may be taken concurrently))

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4331 Systems and Signals Laboratory Cr. 2**

Experiments cover signal generation, signal manipulations and signal measurements, electronic oscillators, steady-state, zero-state and zero-input responses of linear circuits, harmonic sinusoidal content (Fourier Series) of periodic signals, low-pass, high-pass, band-pass and notch filter circuits, network functions, solution of differential equations using operational amplifier circuits, amplitude modulation and demodulation of speech signals, signal sampling and reconstruction. Offered Fall, Winter.

**Prerequisite:** ECE 4330 (may be taken concurrently) with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering.

**ECE 4340 Microcomputer-Based Instrumentation Laboratory Cr. 2**

Multipurpose personal-computer-based approach to real time instrumentation. Current interfacing and software used for data acquisition, transmission, analysis and report writing. Offered Every Term.

**Prerequisites:** (ECE 2610 with a minimum grade of C- or ECE 3610 with a minimum grade of C-), ECE 3570 with a minimum grade of C-, and ECE 3330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$10

**ECE 4470 Control Systems I Cr. 4**

System representations; feedback characteristics; time-domain characteristics; signal flow graph, Routh-Hurwitz criteria; Root Locus Plots; Nyquist criteria, Bode plots; PID, phase-lead and phase-lag controller design. Offered Every Term.

**Prerequisite:** ECE 4330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4570 Fundamentals of Microelectronic Devices Cr. 3**

Aspects of electrical properties of semiconductors, the physical electronics of P-N junction, bipolar, field effect transistors, and device fabrication technology essential to understanding semiconductor active devices and integrated circuits. Introduction to the behavior of semiconductor and electronics devices. Offered Every Term.

**Prerequisites:** ECE 3300 with a minimum grade of C- and (MAT 2150 with a minimum grade of C- or (MAT 2250 with a minimum grade of C- and MAT 2350 with a minimum grade of C-))

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4600 Capstone Design I Cr. 4**

**Satisfies General Education Requirement:** Writing Intensive Competency Design principles, subsystems of microcontrollers; designing products using microcontrollers, sensors and actuators. Offered Every Term.

**Prerequisite:** ENG 3050 with a minimum grade of C- and ECE 3620 with a minimum grade of C- and ECE 4330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students with a class of Senior; enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4680 Computer Architecture Cr. 3**

An introduction to computer architecture. Instruction set architecture; performance analysis of computer systems; basic processor design and implementation techniques; pipelined processor design; design of the control unit, memory hierarchy and cache design; I/O. Offered Yearly.

**Prerequisites:** BE 2100 with a minimum grade of C-, ECE 2610 with a minimum grade of C-, and ECE 3620 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4700 Introduction to Communication Theory Cr. 4**

Basic information transmission concepts. Spectral analysis. Transmission through linear networks. Sampling principles. Digital and analog communication signals and systems. The effect of noise in communication systems. Elementary decision theory. Offered Every Term.

**Prerequisite:** (BE 2100 with a minimum grade of C- or BE 3220 with a minimum grade of C-) and ECE 4330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4800 Electromagnetic Fields and Waves I Cr. 4**

Fundamentals of electromagnetic engineering, static electric and magnetic fields using vector analysis and fields of steady currents, Maxwell's equations and boundary value problems. Basic principles of plane waves, transmission lines and radiation. Offered Every Term.

**Prerequisite:** ECE 3330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4850 Engineering Optics Cr. 4**

Topics include: lightwave fundamentals, optical sources and detectors, optical fibers and waveguides, optical instrumentation, optical sensors for self-driving vehicles and robotics, applications optical devices and systems. Offered Yearly.

**Prerequisite:** ECE 3330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**ECE 4990 Directed Study Cr. 1-4**

Supervised study and instruction in a field selected by the student. Offered Every Term.

**Restriction(s):** Enrollment limited to students with a class of Senior; enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Repeatable for 4 Credits**

**ECE 5100 Quantitative Physiology Cr. 4**

Basic principles of human physiology presented from the engineering perspective. Bodily functions, their regulation and control discussed in quantitative terms and illustrated by mathematical models where feasible. Offered Fall, Winter.

**Equivalent:** BME 5010, CHE 5100, ME 5100

**ECE 5280 Introduction to Cyber-Physical Systems Cr. 3**

Topics include: modeling, design, analysis, and implementation of cyber-physical systems; dynamic behavior modeling, state machine composition, and concurrent computation; sensors and actuators; embedded systems and networks; feedback control systems; temporal logic and model checking. Offered Fall, Winter.

**Prerequisites:** CSC 3100 with a minimum grade of C- and CSC 3110 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the College of Engineering.

**Equivalent:** CSC 5280

**ECE 5330 Modeling and Control of Power Electronics and Electric Vehicle Powertrains Cr. 3**

Basic methodologies for modeling, control system design of renewable power sources and power electronics systems. Offered Fall.

**Prerequisites:** ECE 4470 with a minimum grade of C-

**Restriction(s):** Enrollment is limited to Graduate or Undergraduate level students; enrollment limited to students in the College of Engineering.

**ECE 5340 Advanced Energy Storage Systems for Electrification of Vehicles Cr. 3**

The objective of this course is to learn fundamentals of energy storage systems for electric-based transportation and to provide basic knowledge in the multidisciplinary field of energy storage devices and their applications for land, space and marine vehicles. The focus of the course will be on advanced batteries, supercapacitors, and fuel cells for transportation applications; battery sizing and integration to various land-marine-space vehicles; and the fundamentals of battery management systems including various methodologies in electrical control and thermal management modes. Offered Intermittently.

**Prerequisites:** PHY 2185 with a minimum grade of C

**ECE 5350 Alternative Energy Sources and Conversions Cr. 3**

Covers the fundamentals of alternative energy sources and conversion of these sources to electrical energy. The focus will be on solar and wind energy sources, covering design and operation of photovoltaic cells, solar thermal technologies, and design and operation of wind towers and wind farms. Other topics include: principle operations of geothermal energy, nuclear power plants, hydro-power, tidal and ocean waves and various methods of capturing and transforming these energy resources to electricity. Offered Intermittently.

**Prerequisites:** PHY 2185 with a minimum grade of C

**ECE 5410 Power Electronics and Control Cr. 4**

Control of electric energy using power electronic semiconductor devices; mathematical analysis of circuits containing these devices; design, modeling and control of power converters; applications of power electronic converters. Offered Spring/Summer.

**Prerequisites:** ECE 4330 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the College of Engineering.

**Equivalent:** EVE 5410

**ECE 5425 Robotic Systems I Cr. 4**

Introduction to robot kinematics and control. Computational algorithms for robot movement, sensor fusion, and intelligent behavior, which are needed to build a system that performs actions and interacts with its environment. Offered Fall.

**Prerequisites:** BE 2550 with a minimum grade of C-, BE 1500 with a minimum grade of C-, BME 5020 with a minimum grade of C-, or ECE 3040 with a minimum grade of C-

**Equivalent:** BME 5425

**ECE 5430 Electric Energy Systems Engineering Cr. 4**

Transmission capacity, load characteristics, power frequency control. Energy system component analysis and modeling. Steady-state analysis, load-flow problem and algorithms, optimal dispatch. Transient stability by simulation and direct methods. Offered Intermittently.

**Prerequisites:** ECE 4330 with a minimum grade of C-

**ECE 5440 Computer-Controlled Systems Cr. 4**

Introduction to z-transform and sampling theory. Digital controller design using both transfer function techniques and state space methods.

Implementation aspects of computer-controlled systems. Offered Yearly.

**Prerequisites:** ECE 4470 with a minimum grade of C-, CHE 4600 with a minimum grade of C-, or ME 5540 with a minimum grade of C-

**ECE 5460 Stochastic Processes in Engineering Cr. 4**

Elements of probability theory. Random variables. Random sequences. Convergence concepts, limit theorems and sampling. Gaussain processes and Brownian motion. Martingales and Markov Processes. Frequency-domain analysis. White noise representations. Sampling Theorem. Wiener Filtering. Recursive Filtering. Linear and nonlinear differential systems. Likelihood ratios and applications. Offered Every Other Year.

**Prerequisites:** (IE 3220 with a minimum grade of C- and 1 of (ECE 4330 or ME 5000))

**ECE 5470 Control Systems II Cr. 4**

State space representation of systems; stability and Liapunov methods, controllability and observability, pole placement design using state feedback, observer design, optimal control, linear quadratic regulators, Kalman filter. Offered Yearly.

**Prerequisites:** ECE 4470 with a minimum grade of C-

**ECE 5550 Solid State Electronics Cr. 4**

Physical basis for the opto-electric properties of solids with particular emphasis on semiconductors. Basic principles associated with solid-state devices. Extrinsic and intrinsic semiconductors. Behavior of P-N junctions, bi-polar and field-effect transistors. PC-based simulation of device characteristics using the PC1D simulator. Offered Every Term.

**Prerequisites:** ECE 4800 with a minimum grade of C- and ECE 4570 with a minimum grade of C-

**ECE 5560 Analysis and Design of Analog Integrated Circuits Cr. 3**

The course provides students the fundamentals in Large-Signal/Small-Signal Transistor Modeling, Single-Stage Amplifier Design, Noise, Feedback, Current Mirrors, Differential Amplifiers, Stability, and Frequency Response, Mismatch and Nonlinearity, OpAmp Design, and CAD Tool. Cadence design suite will provide state-of-the-art hands-on experience to analyze, design, and simulate analog circuits. Advanced topics, including Analog and Mixed-Signal Artificial Neural Networks. Offered Fall.

**Prerequisites:** ECE 3330 with a minimum grade of C- and ECE 3570 with a minimum grade of C-

**ECE 5575 Introduction to Micro and Nano Electro Mechanical Systems (MEMS/NEMS) Cr. 3**

General and specialized micro/nanofabrication techniques; basic sensing and actuating mechanisms (piezoresistive, piezoelectric, capacitive, electrostatic, thermal pneumatic, etc.); and design and operation of various MEMS/NEMS devices for automotive and biomedical applications; fabrication and characterization of basic MEMS structures. Offered Fall.

**Prerequisites:** ECE 4570 with a minimum grade of C-

**ECE 5580 Advanced Nanoelectronics Cr. 3**

This course will provide an overview of next generation nanoelectronic devices, with a focus on device operation principles, technology scaling trends, and manufacturing techniques. Course will start with the evolution of MOSFET technology enabled by unprecedented advances in materials, manufacturing techniques and device architecture innovations. Different transistor technologies (i.e. HEMT, TFET) and novel electronic materials beyond Si (i.e. III-Vs, 2D materials, Carbon Nanotubes) will be covered. Following the overview of different memory device technologies, the focus will be shifted to novel computing paradigms. Device technologies that enable neuromorphic and quantum computing, associated fabrication challenges and innovative computation algorithms will be reviewed. Offered Winter.

**ECE 5610 Introduction to Parallel and Distributed Systems Cr. 3**

Fundamentals of parallel and distributed systems. Programming experience in both computing environments. Offered Yearly.

**ECE 5620 Embedded System Design Cr. 4**

Microcontroller architecture and its subsystems. Wired and wireless protocols for vehicular networking applications. Design and implementation of real-time embedded systems. Offered Every Term.

**Prerequisites:** ECE 3620 with a minimum grade of C-

**ECE 5650 Computer Networking and Network Programming Cr. 3**

Overview of networks and the Internet, the application layer, socket programming, the transport Layer, the network Layer, the link Layer: links, access networks, and LANs. Introduction to Software-Defined networking, OpenFlow, and wireless and mobile networks. Projects provide students with hands-on experience in developing network applications. Labs provide students with hands-on experience with network layers and protocols. Offered Every Term.

**Prerequisites:** ECE 4050 with a minimum grade of C-

**ECE 5675 Sensors and Sensor Instrumentation Cr. 4**

Provides students both theoretical background and hands-on skills of sensors and sensor instrumentation, and to prepare students for researches and careers involving sensors and instrumentation. The topics include operating principles of typical sensors, sensing mechanisms (piezoresistive, piezoelectric, capacitive, etc.); sensor instrumentation, amplifiers, noise analysis, and frequency response of readout circuits. Offered Winter.

**Prerequisites:** ECE 3300 with a minimum grade of C-, ECE 3330 with a minimum grade of C-, ECE 3570 with a minimum grade of C-, ECE 4330 with a minimum grade of C-, and ECE 4570 with a minimum grade of C-

**ECE 5680 Computer-Aided Logical Design and FPGAs Cr. 4**

Topics include: review of digital design; advanced applications of Boolean algebra techniques; Computer-Aided Logical Design for large Boolean functions and simplification; threshold function; linear sequential machines; design using Verilog and FPGAs; introduction to cadence. Offered Winter.

**Prerequisites:** ECE 4680 with a minimum grade of C-

**ECE 5690 Introduction to Digital Image Processing Cr. 4**

Provide college engineering seniors and first-year graduate students with introductory preparation in mathematical analysis, vectors, matrices, probability, statistics, sequences and series, and computer programming. Includes concepts of digital image processing from an operational perspective with good exposure to theory, accessibility of DIP to engineering, and a detailed review of current techniques. Offered Fall.

**Prerequisites:** ECE 4050 with a minimum grade of C-, ECE 4330 with a minimum grade of C-, and BE 2100 with a minimum grade of C-

**ECE 5700 Digital Communications Cr. 4**

Digital modulators and demodulators, M-ary PSK, M-ary FSK, optimal receiver for AWGN channel. correlator receiver, matched filter receiver, analysis of probability of bit errors for digital communication systems, Shannon limit, simulation of digital communication system. Offered Intermittently.

**Prerequisites:** ECE 4700 with a minimum grade of C-

**ECE 5770 Digital Signal Processing Cr. 4**

Analysis of discrete signals and systems. Applications to digital filtering, active filters, digital communication and encoding. Offered Yearly.

**Prerequisites:** ECE 4700 with a minimum grade of C-

**ECE 5870 Optical Communication Networks Cr. 4**

Laser and detectors; modulation and demodulation; optical transmitters and receivers; optical filters; optical amplifiers; architecture and network control; multi-access networks; FDDI networks, SONET/SDH, ATM, system performance. Offered Yearly.

**Prerequisites:** ECE 4700 with a minimum grade of C- and ECE 4850 with a minimum grade of C-

**ECE 5880 Introduction to Microwave Engineering Cr. 4**

Introduces students to microwave engineering and prepares them for careers in wireless communications, radars and remote sensing. Topics that will be covered include microstrip lines, coplanar waveguides, scattering parameters, impedance matching, microwave filters, power dividers and directional couplers, nonreciprocal devices, mixers and amplifiers. Offered Yearly.

**Prerequisites:** ECE 4800 with a minimum grade of C- (may be taken concurrently)

**ECE 5990 Directed Study Cr. 1-3**

Supervised study and instruction in the field selected by the student. Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 3 Credits**

**ECE 5995 Special Topics in Electrical and Computer Engineering I Cr. 1-4**

Special subject matter in electrical and computer engineering. Topics to be announced in Schedule of Classes . Offered Every Term.

**Repeatable for 8 Credits**

**ECE 6180 Biomedical Instrumentation Cr. 4**

Engineering principles of physiological measurements, signal conditioning equipment, amplifiers, recorders and transducers. Recent advances in instrumentation. Offered Winter.

**Prerequisites:** BME 5020 with a minimum grade of B- and ECE 3300 with a minimum grade of C-

**Equivalent:** BME 6480, ME 6180

**ECE 6570 Smart Sensor Technology I: Design Cr. 4**

Introduction to various types of sensors and the design of basic analog VLSI circuit building blocks. Offered Winter.

**Equivalent:** BME 6470, PHY 6570

**ECE 6660 Introduction to VLSI Systems Cr. 4**

Survey of very large scale integrated circuit components and design procedures. MOS fabrication, MOS gates, circuit architecture, device design, manufacturing and interface techniques. Offered Yearly.

**Prerequisites:** ECE 2610 with a minimum grade of C-

**Course Material Fees:** \$30

**ECE 6991 Industrial Internship Cr. 1-3**

Internship experience that satisfies the curricular practical training requirements. Offered for graduate credit only. Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 3 Credits**

**ECE 7030 Mathematical Methods in Engineering I Cr. 4**

Introduction to functional analysis. Banach and Hilbert spaces. Fixed-point and projection theorem techniques. Approximation, estimation, and optimization theory. Applications to numerical and error analysis, non-linear equations, and modeling system identification. Offered Yearly.

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7100 Mathematical Modeling in Impact Biomechanics Cr. 4**

Review of models created for impact simulations. Regional impact simulation models. Human and dummy models subject to various restraint systems. Offered Intermittently.

**Prerequisite:** BME 5010 with a minimum grade of B-

**Restriction(s):** Enrollment is limited to Graduate level students.

**Equivalent:** BME 7100, IE 7100, ME 7100

**ECE 7420 Nonlinear Control Systems Cr. 4**

Provide examples of nonlinear dynamical control systems, perform system analysis using phase-portrait, and examine stability using Lyapunov's direct method and invariant set theorems (local and global stability). Introduce describing function method, feedback linearization technique, internal dynamics, and zero-dynamics. Design nonlinear robust controllers. Offered Fall.

**Prerequisite:** ME 6550 with a minimum grade of B- or ECE 5470 with a minimum grade of B-

**Restriction(s):** Enrollment is limited to Graduate level students; enrollment limited to students in the College of Engineering.

**Equivalent:** ME 7590

**ECE 7425 Robotics Systems II Cr. 4**

Project-based class to understand technology that interfaces computer engineering, software design, electronics and sensors with robotics. Advanced application areas of robotics will be covered including medical, military, space, vehicle robotics. Offered Winter.

**Prerequisite:** ECE 5425 with a minimum grade of C or BME 5425 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students; enrollment limited to students in the College of Engineering.

**Equivalent:** BME 7425

**ECE 7430 Discrete Event Systems with Machine Learning Cr. 4**

Discrete event systems and fuzzy discrete event systems; automata and fuzzy automata; supervised learning; languages and operations; supervisory control; controllability, observability, and co-observability, modular control and decentralized control, supervisor synthesis. Offered Fall.

**Prerequisites:** ECE 4330

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7440 Dynamic Systems and Optimal Control Cr. 4**

Formulation of optimal control problems. Pontryagin's maximum principle and necessary conditions for optimality, with applications. Dynamic programming; Hamilton-Jacobi equation; optimal feedback control. Offered Intermittently.

**Prerequisite:** ECE 5440 with a minimum grade of C or ECE 5470 with a minimum grade of C or ME 5550 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7500 Artificial Intelligence for Natural Language Processing Cr. 3**

Natural Language Processing (NLP) is a field in Artificial Intelligence (AI) devoted to creating computer systems that understand and produce human languages. This course will present a broad graduate-level introduction to NLP. We will focus on fundamental methods and algorithms/techniques in NLP. We will also explore several NLP applications, such as sentiment analysis, information extraction, syntactic parsing, and semantic analysis. Offered Fall.

**Prerequisite:** CSC 5800 with a minimum grade of C or CSC 5825 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7530 Advanced Digital VLSI Design Cr. 4**

Topics include: review of VLSI Design processes; CADENCE tools used to simulate and generate the schematic and layout of the synthesized hardware description language codes; and chip fabrication. Offered Winter.

**Prerequisite:** ECE 5680 with a minimum grade of C and ECE 6660 with a minimum grade of C

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7570 Smart Sensor Technology II: Characterization and Fabrication Cr. 4**

Integration of ongoing research in integrated technology of smart sensors. Design of smart sensor devices using computer simulation. Fabrication of smart sensor. Offered Spring/Summer.  
**Prerequisite:** ECE 6570 with a minimum grade of B- or BME 6470 with a minimum grade of B- or PHY 6570 with a minimum grade of B-  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Course Material Fees:** \$50  
**Equivalent:** BME 7470, PHY 7580

**ECE 7590 Biomedical Microsystems Cr. 4**

Biomedical microsystems, with a focus on microfluidics and lab-on-a-chip technologies for medical diagnostics and biological research. Broad coverage of microscale physics; microfabrication methods; separation, purification, and other on-chip processes; biosensing. Offered Fall.  
**Prerequisite:** ECE 5575 with a minimum grade of B- or ECE 6570 with a minimum grade of B- or BME 6470 with a minimum grade of B-  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Equivalent:** BME 7490, CHE 7490

**ECE 7610 Advanced Parallel and Distributed Systems Cr. 3**

Advanced topics in parallel and distributed computing, multicore and parallel architecture, communication, synchronization, parallel algorithms and programming, load balancing and scheduling, security. Offered Winter.  
**Prerequisite:** ECE 5610 or ECE 5650  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7640 Online and Adaptive Methods for Machine Learning Cr. 3**

Introduction to state-of-the-art online learning algorithms with an emphasis on algorithm design and theoretical analysis. Offered Intermittently.  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7650 Scalable and Secure Internet Services and Architecture Cr. 3**

Advanced principles of distributed and cloud computing systems, Internet servers and data centers, content delivery networks, software-defined networking, Internet of things, multimedia networking, performance scalability, energy-aware resource management, security, cost-effective engineering design. Offered Winter.  
**Prerequisite:** ECE 5610 with a minimum grade of C or ECE 5650 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7660 Parallel Computer Architecture Cr. 4**

Review of parallel computer architectures, including symmetric multiprocessors and scalable machines. Parallel software basics for various architectures. Fundamental issues including cache coherence, interconnection network, and synchronization; influence of these on performance of applications. Offered Yearly.  
**Prerequisite:** ECE 5610 with a minimum grade of C and ECE 5620 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7680 Advanced Digital Image Processing and Applications Cr. 4**

Advanced aspects, algorithms, methods in digital image processing and their corresponding applications in different fields. Students develop comprehensive skills and knowledge in digital image processing. Offered Yearly.  
**Prerequisite:** ECE 5690 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7690 Fuzzy Systems Cr. 4**

From basic fuzzy set theory to advanced topics such as neuro-fuzzy systems. Offered Yearly.  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7700 Statistical Communication Theory Cr. 4**

Decision theory, binary decisions with single and multiple observations, signals in additive Gaussian noise, sequential decision theory, estimation theory, Kalman filtering. Offered Yearly.  
**Prerequisite:** ECE 5700 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7730 Telematics Cr. 4**

Introduction to automotive telematics, mobile communication channels, error correction, automatic crash response, vehicle diagnostics, vehicle tracking, vehicle safety, navigation, and current topics in telematics. Offered Winter.  
**Prerequisites:** ECE 5700 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7740 Medical Imaging Systems Cr. 3**

Exposes students to the world of medical and biomedical imaging with emphasis on principles, approaches and applications of each modern imaging modality. Basic knowledge of MATLAB programming language is required. Offered Fall.  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Equivalent:** BME 7730

**ECE 7850 Photonics Cr. 4**

Topics include: light-matter interaction using the concepts of rays, electromagnetic waves, and quanta of light; electronic and photonic properties of materials; photonic devices for applications in communication, signal processing, data storage, and sensing; photonic solutions for quantum technologies in cryptography, communication, and computing. Offered Yearly.  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7860 Operation and Control of Modern Power Systems Cr. 4**

Topics include power system optimal dispatch; power system stability analysis and control; smart grid technologies and applications, covering modeling and control of renewable energy systems; distributed generation; microgrid architecture and control; demand response; energy storage for power grids; grid interface and integration of renewable sources; and electricity market fundamentals. Offered Fall.  
**Prerequisite:** ECE 5430 with a minimum grade of C  
**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 7990 Directed Study Cr. 1-8**

Supervised study and instruction in an advanced topic. Offered Every Term.  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Repeatable for 12 Credits**

**ECE 7995 Special Topics in Electrical and Computer Engineering II Cr. 1-4**

A consideration of special subject matter in electrical and computer engineering. Topics to be announced in Schedule of Classes. Offered Every Term.  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Repeatable for 12 Credits**

**ECE 7996 Research Cr. 1-8**

Design, investigation and experimental work on some phase of electrical and computer engineering. Written report required. Offered Every Term.  
**Restriction(s):** Enrollment is limited to Graduate level students.  
**Repeatable for 8 Credits**

**ECE 8999 Master's Thesis Research and Direction Cr. 1-6**

Offered Every Term.  
**Restriction(s):** Enrollment limited to students with a class of Candidate Masters; enrollment is limited to Graduate level students.  
**Repeatable for 6 Credits**

**ECE 9990 Pre-Doctoral Candidacy Research Cr. 1-8**

Research in preparation for doctoral dissertation. Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 12 Credits**

**ECE 9991 Doctoral Candidate Status I: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 9992 Doctoral Candidate Status II: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** ECE 9991 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 9993 Doctoral Candidate Status III: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** ECE 9992 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 9994 Doctoral Candidate Status IV: Dissertation Research and Direction Cr. 7.5**

Offered Every Term.

**Prerequisite:** ECE 9993 with a minimum grade of S

**Restriction(s):** Enrollment is limited to Graduate level students.

**ECE 9995 Candidate Maintenance Status: Doctoral Dissertation Research and Direction Cr. 0**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Course Material Fees:** \$402.01

**Repeatable for 0 Credits**

**ECE 9997 Doctoral Seminar Cr. 1-4**

Offered Every Term.

**Restriction(s):** Enrollment is limited to Graduate level students.

**Repeatable for 4 Credits**