Electrical and Computer Engineering (ECE)

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5101. Introduction to System Theory

Three credits. Recommended preparation: ECE 3101.

Modeling and analysis of linear systems. Introduction to functions of a complex variable. Linear algebra with emphasis on matrices, linear transformations on a vector space, and matrix formulation of linear differential and difference equations. State variable analysis of linear systems. Transform methods using complex variable theory, and time-domain methods including numerical algorithms.

5121. Multivariable Digital and Robust Control Systems

Three credits. Prerequisite: Instructor consent.

Analysis and design of robust multivariable control systems incorporating a digital computer as the controlling element. Topics include: Mathematical models of discrete-time systems, Discretization of continuous-time systems, Measures of control system performance, Classical single input-single output design methods, Compensator design via discrete-equivalent and direct design methods, State variable design via discrete equivalent and pole placement methods, Linear quadratic regulator (LQR) control, H2 and H-infinity optimal control, numerical optimization and nonlinear control.

5201. Electromagnetic Wave Propagation

Three credits.

Engineering application of Maxwell's field theory to electromagnetic wave propagation in various media. Reflection, refraction, diffraction, dispersion, and attenuation. Propagation in seawater and in the ionosphere.

5211. Semiconductor Devices and Models

Three credits.

Band theory, conduction in semiconductors, carrier statistics, deep levels, impurities with multiple charge states, heavy doping effects, non-uniform doping. Non-equilibrium processes, carrier scattering mechanisms, the continuity equation, avalanche multiplication, carrier generation, recombination, and lifetime. P-n junctions, non-abrupt junctions, various injection regimes, and device models. Metal semiconductor junctions, current transport mechanisms, and models. BJT, JFET, MESFET, and MOSFET, and device models.

5212. Fundamentals of Opto-Electronic Devices

Three credits.

Absorption and emission mechanisms in direct and indirect semiconductors. Semiconductor optoelectronic devices such as light-emitting diodes, injection lasers, photocathodes, solar cells, and integrated optics.

5223. Nanophotonics

Three credits. Prerequisite: ECE 3223 or instructor consent.

Principles and applications of nanophotonics with focus on optical metamaterials, plasmonics, and photonic bandgap crystals. Topics covered include electric plasma, magnetic plasma, optical magnetism, negative index metamaterials, localized and non-localized surface plasmon polaritons, photonic bandgap structures, superlens, optical cloaking, surface enhanced Raman spectroscopy, transformation optics, plasmonic sensors, plasmonic waveguides.

5225. Electron Device Design and Characterization

Three credits. Prerequisite: Instructor consent. Recommended preparation: ECE 4211.

Recommended Preparation: ECE 4211 or equivalent course Design and evaluation of micro/nano electronic devices using state-of-the-art computer simulation tools, experimental electrical characterization of semiconductor devices and overview of modern electronic devices such as high-performance MOSFETs, TFTs, solar cells, non-volatile memories, CCDs, thermoelectric power generators. The electronic device (such as nanometer scale field effect transistor) design project will involve use of Synopsys tools to simulate the fabrication process, device simulation and performance evaluation.

5231. Fund of Photonics

Three credits. Prerequisite: Instructor consent.

Principles of optics including rays, waves, beams, electromagnetics, polarization and statistics. Basic postulates, simple optical components, graded index and matrix optics, monochromatic waves, interference, polychromatic light, Gaussian beams and propagation, diffraction, Fourier transforms, holography, dispersion and pulse propagation, polarizing devices and applications. Concepts of coherence and partial coherence as applied to various light sources in optical experiments and systems.

5232. Optoelectronic Devices

Three credits.

Optoelectronic devices as applied to fiber optic communications, optical switching and interconnects. Semiconductor laser devices, including dc, ac small signal, ac large signal, and noise with emphasis upon analytical models. Vertical cavity devices and technology. Semiconductor optical amplifiers, waveguide and vertical cavity modulators, photodetectors, optical switches, receivers and transmitters. Techniques for OE integration and the relevance of bipolar and field-effect devices for monolithic integration. Technologies for optoelectronic integration for telecom and datacom optical interconnect. WDM techniques for optical networks.

5242. Micro-Optoelectronic Devices and IC Fabrication

Three credits. Prerequisite: ECE 3221 and 4211; not open for credit to students who have passed ECE 4242.

Semiconductor wafer characterization using Hall effect, X-ray diffraction, and Photoluminescence; Semiconductor wafer processing using Diffusion, Oxidation, Epitaxial growth and/or Qdot self-assembly, Photolithographic techniques; Project work including design, modeling and fabrication of solar cells, FETs, Memory, LED and Lasers, sensors, and IC building blocks for digital and analog circuits.

5261. Memory Device Technologies

Three credits. Not open for credit to students who have passed ECE 4261.

Current and future digital solid-state memory device technologies including DRAM, SRAM, flash memory, ferroelectric memory, magnetoresistive memory, phase-change memory and resistive memory, with an emphasis on the underlying physical mechanisms.

5402. Computer Architecture

Three credits. Recommended preparation: CSE 4302 or the equivalent.

Provides an in-depth understanding of the inner workings of modern digital computer systems. Traditional topics on uniprocessor systems such as performance analysis, instruction set architecture, hardware/software pipelining, memory hierarchy design and input-output systems will be discussed. Modern features of parallel computer systems such as memory consistency models, cache coherence protocols, and latency reducing/hiding techniques will also be addressed. Some experimental and commercially available parallel systems will be presented as case studies.

5451. Introduction to Hardware Security and Trust

Three credits. Prerequisite: ECE 3401. This course and ECE 4451 may not both be taken for credit.

Fundamental hardware security and trust issues related to integrated circuits. Cryptographic hardware, physical and invasive attacks, side-channel attacks, physically unclonable functions, hardware-based true random number generators, watermarking of Intellectual Property (IP) blocks, FPGA security, IC/IP piracy, access control, hardware Trojan detection and prevention in IP cores and integrated circuits.

5510. Power System Analysis

Three credits. Prerequisite: ECE 2001 or equivalent.

Fundamentals of power system planning, operation, and management. Power generation and distribution. Modeling of AC generator, AC and DC motors, transformer and cable. Power flow solution. Modern power system monitoring/control, fault analysis, and transient stability analysis using computer tools. Use of power system simulation tools for power system planning and design.

5512. Power Distribution

Three credits. Prerequisite: ECE 3231.

Principles of distribution system planning, automation and real-time operation with applications. Concepts of AC/DC Electricity. Three-phase power distribution as well as DC and Hybrid circuits. Load flow calculations, fault analysis, and reliability evaluation. Distributed power resources. Distribution system protection and reconfiguration. Smart distribution technologies. Efficient and resilient energy utilization.

5520. Advanced Power Electronics

Three credits. Prerequisite: ECE 3211.

Advanced converter and inverter topologies for high efficiency applications. Non-ideal component characteristics. Necessary components such as gate drive circuits and magnetic component design (that are not covered in introductory power electronics courses).

5530. Modeling and Control of Electric Drives

Three credits. Prerequisite: ECE 3212.

Several topics related to modeling and control of electric drives. Fundamental equations related to inductance and flux variations in a rotating machine, leading to torque production. Reference frame theory and transformations for modeling purposes. Dynamic models of three-phase induction and permanent-magnet synchronous machines. Basic modeling of power electronic converters for electric drives, with focus on three-phase DC/AC inverters. Various control strategies with focus on vector control and different power electronic switching schemes in electric drives.

5540. Electrical System Protection and Switchgear

Three credits. Prerequisite: Instructor consent.

Methods to sense voltage and current in medium and low voltage applications. Voltage sensing techniques include differential voltage amplifiers, shunt voltage measurement, and potential transformers. Current sensing techniques include current transformers, Rogowski coils, series voltage measurement, and Hall-effect sensors. Solid-state and mechanical relays and timing functions. Fuses and circuit breakers at medium voltage levels with focus on ratings, application-specific selection, and response time. Protection methods, e.g. differential protection, of transformers, generators, and cables with focus on distance relays and specialized devices.

5544. Electrical Insulation System

Three credits. Recommended preparation: ECE 3001 and 3231 or equivalent; instructor consent required.

Introduction to electrical insulation system for low and medium voltages. Gas discharge physics and dielectrics. Sulfur hexafluoride. Outdoor insulation. Dielectric breakdown in liquids and solids. Power capacitors and inductors. MV cables and accessories. Voltage transients in MV power systems. Thermal model for MV transformers (steady-state, transient, and hot-spot temperatures identification and verification). Insulation coordination design for MV transformers, load capacity and service lifting trade-off study based on electrical and thermal over-stress analysis. Insulation system for MV and LV rotating machines (form and random wound), insulation system optimization for torque density and payload efficiency. Insulation system testing and qualification. Monitoring and diagnosis.

6094. Seminar

One credit. May be repeated for a maximum of eight credits. Students taking this course will be assigned a final grade of S (satisfactory) or U (unsatisfactory).

Presentation and discussion of advanced electrical engineering problems.

6095. Special Topics in Electrical and Systems Engineering

Variable (1-3) credits. May be repeated for credit.

Classroom and/or laboratory courses in special topics as announced in advance for each semester.

6099. Independent Study in Electrical Engineering

Variable (1-6) credits. Prerequisite: Instructor consent. May be repeated for credit.

Individual exploration of special topics as arranged by the student with an instructor of his or her choice.

6102. Optimal and Model Predictive Control

Three credits. Prerequisite: ECE 5101 and 6111; instructor consent required.

Optimal Control, including optimization techniques for linear and nonlinear systems, calculus of variations, dynamic programming, the Pontryagin maximum principle, and computational methods. Linear Model Predictive Control, including process models and model prediction methods of state space description, transfer matrix representation, and neural network representation; and optimization methods without and with constraints. Nonlinear Model Predictive Control.

6103. Nonlinear System Theory

Three credits. Prerequisite: ECE 5101.

Stability of time-varying nonlinear systems. Liapunov's direct method. Describing functions. Popov’s stability criterion. Adaptive control.

6104. Information, Control and Games

Three credits. Prerequisite: ECE 5101 and 6111.

Problems of dynamic optimization where more than one decision maker is involved, each having own payoff and access to different information. Rules of the game and roles of information; Dynamic games with symmetric information or incomplete information or asymmetric information; Moral hazard; Mechanism design; Signaling, Auctions and Pricing.

6108. Linear Programming and Network Flows

Three credits. Prerequisite: ECE 5101.

Computational methods for linear programming with special emphasis on sequential and parallel algorithms for Network Flow Problems. Standard and canonical forms of linear programming, revised Simplex methods, basis updates, decomposition methods, duality, shortest paths, minimal spanning trees, maximum flows, assignment problems, minimum cost network flows, and transportation problems.

6111. Applied Probability and Stochastic Processes

Three credits.

Statistical methods for describing and analyzing random signals and noise. Random variables, conditioning and expectation. Stochastic processes, correlation, and stationarity. Response of linear systems to stochastic inputs. Applications.

6121. Information Theory

Three credits. Prerequisite: ECE 6111.

Basic concepts: entropy, mutual information, transmission rate and channel capacity. Coding for noiseless and noisy transmission. Universal and robust codes. Information-theoretic aspects of multiple-access communication systems. Source encoding, rate distortion approach.

6122. Digital Signal Processing

Three credits.

Discrete-time signals and systems. The z-transform. The Discrete Fourier Transform (DFT). Convolution and sectioned convolution of sequences. IIR and FIR digital filter design and realization. Computation of the DFT: The Fast Fourier Transform (FFT), algorithms. Decimation and interpolation. Parametric and nonparametric spectral estimation. Adaptive filtering. Finite word length effects.

6123. Advanced Signal Processing

Three credits. Prerequisite: ECE 6111 and 6122.

Wiener filter theory. Linear prediction. Adaptive linear filters: LMS and RLS algorithms, variants, lattice structures and extra-fast implementation. Convergence properties. High-resolution spectral estimation. Hidden Markov models, Monte-Carlo methods for signal processing. Multiresolution decomposition and wavelets. Blind methods.

6124. Advanced Signal Detection

Three credits.

Focus on discrete-time detection of signals in noise that is not necessarily Gaussian. Topics include: classical Neyman-Pearson and Bayes theory, efficacy and asymptotic relative efficiency; some canonical noise models; quantized detection; narrowband signal detection; distance measures and Chernoff bounds; sequential detection; robustness; non-parametric detection; continuous-time detection and the Karhunen-Loève expansion.

6125. Digital Image Processing

(Also offered as BME 6125.) Three credits.

Problems and applications in digital image processing, two-dimensional linear systems, shift invariance, 2-D Fourier transform analysis, matrix Theory, random images and fields, 2-D mean square estimation, optical imaging systems, image sampling and quantization, image transforms, DFT, FFT, image enhancement, two-dimensional spatial filtering, image restoration, image recognition, correlation, and statistical filters for image detection, nonlinear image processing, and feature extraction.

6126. Fundamentals of Optical Imaging

(Also offered as BME 6126.) Three credits.

Learning optical imaging fundamentals. Topics include: review of two-dimensional linear system theory; scalar diffraction theory, wave optics, Fresnel and Fraunhofer diffraction; imaging properties of lenses; image formation; optical resolution in imaging, frequency analysis of optical imaging systems; imaging with coherent and incoherent sources, coherent transfer function; optical transfer function, point spread function, fundamentals of microscopy, two-dimensional spatial filtering; coherent optical information processing; frequency-domain spatial filter synthesis; holography.

6141. Neural Networks for Classification and Optimization

Three credits.

This course provides students with an understanding of the mathematical underpinnings of classification techniques as applied to optimization and engineering decision-making, as well as their implementation and testing in software. Particular attention is paid to neural networks and related architectures. The topics include: Statistical Interference and Probability Density Estimation, Single and Multi-layer Perceptions, Radial Basis Functions, Unsupervised Learning, Preprocessing and Feature Extraction, Learning and Generalization, Decision Trees and Instance-based Classifiers, Graphical Models for Machine Learning, Neuro-Dynamic Programming.

6143. Pattern Recognition and Neural Networks

(Also offered as BME 6143.) Three credits.

Review of probability and stochastic processes. Statistical pattern recognition. Nonlinear signal processing and feature extraction. Correlation filters. Metrics for pattern recognition. Baysian classifiers. Minimum probability of error processors. Supervised and unsupervised learning. Perception learning methods. Multilayer neural networks. Applications to security and encryption.

6151. Communication Theory

Three credits. Prerequisite: ECE 6111.

Design and analysis of digital communication systems for noisy environments. Vector representation of continuous-time signals; the optimal receiver and matched filter. Elements of information theory. Quantization, companding, and delta-modulation. Performance and implementation of common coherent and non-coherent keying schemes. Fading; intersymbol interference; synchronization; the Viterbi algorithm; adaptive equalization. Elements of coding.

6152. Wireless Communication

Three credits. Prerequisite: ECE 6122 and 6151.

Introduces basic concepts in wireless communication and networks with emphasis on techniques used in the physical layer of current and future wireless communication systems. Covers channel modeling, modulation, spread spectrum techniques, multiuser communication theory, wireless network protocols, and current cellular and PCS systems. Special topics in equalization and array signal processing are included.

6161. Modern Manufacturing System Engineering

Three credits.

Issues and methods in modern manufacturing systems. Integrated product and process development. Design for quality, on-line quality control and improvement, reliability during product development, and design for testability. Computer-aided production management, production planning and scheduling, and optimization-based planning and coordination of design and manufacturing activities. Targeted toward students, professional engineers, and managers who want to have an impact on the state-of-the-art and practice of manufacturing engineering, and to improve manufacturing productivity.

6171. Mobile Robotics

Three credits. Recommended preparation: MATH 2410; MATH 3160 or STAT 3345; ECE 3111; familiarity with MATLAB programming.

Coordinate transformation, kinematics and dynamics, sensor modeling, specifics of camera sensors, inertial measurement unit (IMU) sensor, simultaneous localization and mapping (SLAM), EKF-SLAM, Monte Carlo localization, SLAM observability, robot control, specifics of vision-based control, and aspects of Human-robot interaction; class project with a project report.

6211. Antenna Theory and Applications

Three credits.

Analysis and synthesis of antenna systems including electric- and magnetic-dipole, cylindrical, helical, reflector, lens, and traveling-wave antennas. Theory of arrays including patterns, self and mutual impedances.

6212. Microwave Techniques

Three credits.

A theoretical analysis of microwave components, systems, and measuring techniques. Scattering matrix analysis is applied to microwave devices having two or more ports.

6222. Advanced Semiconductor Devices

Three credits.

Fundamental properties of heterostructures, strained-layer superlattices, NIPI structures, multiple quantum well, quantum wire, and quantum dot structures. Operation, modelling of the electrical characteristics, design, and applications of HBJT, HEMT, and resonant tunneling devices. Second-order effects in submicron MOSFETs and MESFETs.

6226. Power Network Dynamics and Simulation

Three credits. Prerequisite: ECE 5101 or 6122 or instructor consent.

Introduction to power network dynamics with emphasis on numerical simulation techniques. Numerical integration rules for large-scale power networks, numerical oscillation and its solution, power system components, frequency-dependent transmission network, nonlinear elements, network equivalents, power network stability. Applications of network simulation to microgrid stability analysis and control design. Real-time simulation algorithms for interdependent infrastructures analysis.

6231. Advanced Optoelectronics

Three credits. Prerequisite: ECE 5212.

Review of optoelectronic devices and integrated circuit (IC) technologies (analog and digital); logic gates; self-electro-optic devices (SEEDs), microlasers, Fabry-Perot (F-P) etalons and optoelectronic IC (OEICs); modulators: F-P modulators (absorptive and refractive), spatial light modulators (SLMs) and their applications; bistable devices; bistable laser amplifiers, resonant tunneling transistor lasers, and polarization bistability; optical interconnects; architectural issues and optical processors based on S-SEED, optical neural networks, and other devices.

6232. Nonlinear Optical Devices

Three credits. Prerequisite: ECE 5231.

Wave propagation in nonlinear media, generation of harmonics in optical materials, optical parametric processes, stimulated emission and scattering processes. Device modeling and application of fiber and semiconductor lasers, optical amplifiers and modulators. Electro-optic, acousto-optic, and magneto-optic devices. Soliton generation and propagation.

6242. VLSI Fabrication Principles

Three credits. Prerequisite: Instructor consent.

Semiconductor materials and processing, emphasizing compound semiconductors, optoelectronic materials, shallow devices, and fine-line structures. Semiconductor material properties; phase diagrams; crystal growth and doping; diffusion; epitaxy; ion implantation; oxide, metal, and silicide films; etching and cleaning; and lithographic processes.

6243. Nanotechnology

Three credits.

Nanoelectronic and optoelectronic devices: Quantum confinement in 1D, 2D and 3D (quantum wells, wires, and dots) structures; density of states and carrier density in low-dimensional structures; fabrication methodology for quantum wire transistors and lasers; single-electron transistors/tunneling devices; growth and characterization of nanostructured materials with grain sizes in the range of 10-50 nm. Organic monolayers: Langmuir-Blodgett monolayers, Self-Assembled monolayers, Multi-layer structures, technological applications of organic thin films.

6244. Nanotechnology - II (Laboratory Course)

Three credits. Prerequisite: Instructor consent.

Growth and characterization of carbon nanotubes using vapor phase nucleation; Growth of cladded quantum dots using liquid and/or vapor phase techniques; Characterization using AFM and TEM and Dynamic scattering techniques; Nano-device processing highlighting E-Beam lithography, and self-assembly techniques; Project work involving fabrication of devices including LEDs, FETs and memor, detectors and sensors using quantum dots and nanotubes/wires.

6246. Heteroepitaxy of Semiconductors

Three credits. Prerequisite: Instructor consent.

Properties of semiconductors, including crystal structure, elastic properties, and properties of defects. Surface considerations in heteroepitaxy. Heteroepitaxial growth methods, including molecular beam epitaxy and metalorganic vapor phase epitaxy. Mismatched heteroepitaxy of a single, uniform layer, including pseudomorphic growth, equilibrium considerations, kinetically-limited strain relaxation, and threading dislocations. Design and growth of graded and multilayered metamorphic structures, and dislocation dynamics in them. Characterization of heteroepitaxial structures. Defect and strain engineering in semiconductor heterostructures.

6421. Advanced VLSI Design

Three credits. Recommended preparation: ECE 3421 and ECE 3302 (or equivalent).

Advanced concepts of circuit design for digital VLSI components in state of the art MOS technologies. Emphasis is on the circuit design, optimization, RTL design, synthesis, and layout of either very high speed, high density or low power circuits and systems for use in applications such as micro-processors, signal and multimedia processors, memory and periphery. Other topics include challenges facing digital circuit designers today and in the coming decade, such as the impact of scaling, deep submicron effects, interconnect, signal integrity, power distribution and consumption, and timing.

6422. VLSI CAD Algorithms

Three credits.

Very large-scale integrated circuit (VLSI) computer-aided design (CAD) tools, optimization techniques, and design automation algorithms, such as branch and bound, genetic algorithms, simulated annealing, and linear programing. VLSI physical design process including partitioning, floor planning, placement, routing, compaction, and pin assignment.

6432. VLSI Design Verification and Testing

Three credits. Prerequisite: Instructor consent.

Introduction to the concepts and techniques of VLSI (very large scale integration) design verification and testing, details of test economy, fault modeling and simulation, defects, automatic test pattern generation (ATPG), design for testability (DFT), scan and boundary scan architectures, built-in self-test (BIST) and current-based testing. State-of-the-art tools are used for ATPG, DFT, test synthesis and power analysis and management.

6435. Advanced Numerical Methods in Scientific Computation

Three credits. Prerequisite: ECE 5101.

Development, application and implementation of numerically stable, efficient and reliable algorithms for solving matrix equations that arise in modern systems engineering. Computation of matrix exponential, generalized inverse, matrix factorizations, recursive least squares, eigenvalues and eigenvectors, Lyapunov and Riccati equations.

6437. Computational Methods for Optimization

Three credits. Prerequisite: ECE 5101.

Computational methods for optimization in static and dynamic problems. Ordinary function minimization, linear programming, gradient methods and conjugate direction search, nonlinear problems with constraints. Extension of search methods to optimization of dynamic systems, dynamic programming.

6439. Estimation Theory and Comp Algorithms

Three credits. Prerequisite: ECE 5101 and 6111.

Estimation of the state and parameters of noisy dynamic systems with application to communications and control. Bayesian estimation, maximum-likelihood and linear estimation. Computational algorithms for continuous and discrete processes, the Kalman filter, smoothing and prediction. Nonlinear estimation, multiple model estimation, and estimator Kalman, multiple model estimation, and estimator design for practical problems.