Electrical and Computer Engineering

Chair

- Er-Wei Bai

Undergraduate majors: computer science and engineering (B.S.E.); electrical engineering (B.S.E.)
Graduate degrees: M.S. in electrical and computer engineering; Ph.D. in electrical and computer engineering
Faculty: https://ece.engineering.uiowa.edu/people
Website: https://ece.engineering.uiowa.edu/

Electrical engineers and computer engineers make vital contributions to nearly all facets of modern society through their work in areas, such as computer systems, software applications, medical imaging, robotics, wireless communications, and fiber optics. From smart technologies to high-definition television, cellular telephones, and computer networks, the contributions of electrical and computer engineers are constantly reinventing the world.

Many benefits that have sprung from electrical and computer engineering technology now are taken for granted—noninvasive imaging of the brain and other internal organs, astonishing views of the solar system's outer planets, and wireless telecommunications. Electrical and computer engineers also play crucial roles in major emerging technologies, such as driverless vehicles, smart cities, and human genomics.

As the United States strives to retain or enlarge its share of national and international markets, electrical and computer engineers will play a more important role in fostering innovation, increasing productivity, and creating intelligent systems to improve the quality of life for residents.

Electrical and computer engineers work in research, design, development, manufacturing, sales, market analysis, consulting, field service, and management. They are employed in computer, semiconductor, software, aerospace, telecommunication, medical, radio, television, and power industries, and many graduates pursue entrepreneurial ventures.

Certificate in Wind Energy

The Departments of Mechanical and Industrial Engineering, Civil and Environmental Engineering, and Electrical and Computer Engineering and the Department of Geographical and Sustainability Sciences (College of Liberal Arts and Sciences) administer the undergraduate certificate program in wind energy; see the Certificate in Wind Energy in the Catalog.

Programs

Undergraduate Programs of Study

Majors

- Major in Computer Science and Engineering (Bachelor of Science in Engineering)
- Major in Electrical Engineering (Bachelor of Science in Engineering)

Graduate Programs of Study

Majors

- Master of Science in Electrical and Computer Engineering
- Doctor of Philosophy in Electrical and Computer Engineering

Research and Study Areas

Bioinformatics and Computational Biology

The Center for Bioinformatics and Computational Biology (CBCB) is a multidisciplinary research enterprise that encompasses numerous laboratories and collaborates with many graduate programs on campus. Students may earn the Certificate in Informatics (Graduate College), to augment their Ph.D. training in disciplines ranging from molecular biology to biochemistry to computer science to engineering.

The Coordinated Laboratory for Computational Genomics, a CBCB affiliate, engages in a broad range of research activities that complement the Human Genome Project. Members of the laboratory develop new hardware and software techniques for analysis and annotation of genomic sequence, its transcription and translation, and the proteome. Other efforts are aimed at systematic capture and curation of phenotypic information acquired from massive databases of clinical information derived from collaborations with the Carver College of Medicine. The goal of these projects is to elucidate the mechanisms of human disease and develop promising new methods for cures and treatments.

The laboratory's facilities include more than 200 workstations, three Linux clusters, and access to the NSF TeraGrid and other high-performance computing facilities. Projects in the laboratory frequently involve cutting-edge genomic and proteomic instruments such as the Roche 454 next-generation sequencing platform and several high-throughput gene expression (microarray) measurement platforms.

Computer Systems and VLSI Circuits

Research emphasis is directed toward design and testing of very-large-scale integrated (VLSI) circuits, high-performance computing and networking, and intelligent agent systems. Research in the VLSI area involves development of techniques and algorithms that assist in synthesis and testing of large-scale logic circuits, and incorporation of these techniques into computer-aided design tools. Current projects include new pattern sources for built-in-test, efficient test pattern generation, generation of compact test sets, and methods for reducing test data volumes.

High-performance computing research involves development of collaborative and parallel computing environments and associated software tools, and use of these facilities and tools in varied application domains, including image processing and computational biology. Current work in networking focuses on protocols and layer-integration schemes that support high-performance wireless networking, and on control and coordination of mobile ad hoc networks. Current research facilities in these areas include several large cluster

computers and an experimental asynchronous transfer mode (ATM) network.

Departmental facilities that support this work include Linux and Windows workstations and server nodes that provide college-wide networked computer services. Advanced computing facilities also are available at national supercomputing centers and federal laboratories.

Control Systems and Systems Theory

Control systems and system theory use feedback to improve the predictability and efficiency of engineered systems ranging from electronic amplifiers to vehicle guidance systems, manufacturing processes, communication channels, and the Internet. Work in control systems and systems theory draws heavily on results from mathematics, physics, and computer science to model the systems that are to be controlled and to implement feedback controllers.

Current research emphasizes optimal, adaptive, digital, robust, and stochastic control and the control of discrete event dynamical systems. Recent work has concerned the estimation, identification, and robust control of linear and nonlinear dynamical systems; set membership identification, control over wireless communication channels; coordinated fault tolerant control of unmanned vehicles; use of control theory to analyze distributed computing, communications, and manufacturing systems; interplay between communications and control; design of fast digital controllers using subband coding; and multirate control systems.

Research in control systems and systems theory is supported by extensive computing resources and collaborations with local industry, the Center for Computer-Aided Design, the National Advanced Driving Simulator (NADS), and the Carver College of Medicine.

Nanoscale Electronics and Spintronics

Nanoscale devices and systems provide solutions for low-power logic devices, high-density 3-D stackable electronic and/or spintronic memory elements, and solar/waste energy harvesting applications. Current nanoscale and spintronics work involves post-CMOS transistor research to extend Moore's law in this century; use of novel magnetic and nonmagnetic nanomaterials for enhanced-CMOS and nonvolatile memory; and intelligent solar cells, thermoelectric devices, fuel cells and batteries for efficient solid-state energy conversion. Departmental researchers are pursuing experimental, theoretical, and large-scale computational approaches.

Signal and Image Processing

Research in image processing and basic and applied signal processing is supported by a digital signal processing laboratory and an image analysis laboratory. Collaborative research with faculty in the Departments of Radiology, Neurology, Psychiatry, Internal Medicine, Ophthalmology and Visual Sciences, Radiation Oncology, and Biomedical Engineering is directed at quantitative analysis of medical images.

In the area of signal processing, current projects include analysis and design of efficient adaptive algorithms for signal processing, efficient coding and transmission of speech, speech processing aids for the hearing-impaired, robust equalization of uncertain channels, application of neural networks to communications systems, multirate signal processing, and subband coding and channel equalization.

Image processing and analysis projects include development of novel methods for image segmentation, image registration, computer-aided detection and diagnosis, early identification of disease patterns from medical image data, computer-aided surgical planning, virtual and augmented reality medical image visualization, building anatomic atlases, and a broad range of translational medicine projects focusing on research and clinical applications of the novel methods. The areas of interest span all scales, from molecules to cells to small animals to humans, and cover a broad range of organ systems and targeted diseases. The spectrum of medical imaging modalities used for research and applications in image processing and analysis is equally broad, encompassing all existing modalities, including X-ray, CT, MR, PET, SPECT, and OCT.

The Medical Image Analysis Labs consist of several specialized facilities for digital image processing. They are equipped with state-of-the-art devices for data storage, transfer, visualization, and analysis. High-capacity data storage devoted to image processing research offers more than 35 TB of online hard disk space. An augmented reality medical image visualization lab serves as a high-performance collaborative resource for the Iowa Institute for Biomedical Imaging. The institute makes additional resources available to image processing research, including small and large animal as well as human research scanning facilities, and provides a backbone for interdisciplinary medical image analysis research to electrical and computer engineering graduate students and faculty.

Waves and Materials

Research in this area is carried out primarily in the Iowa Advanced Technology Laboratories, a well-equipped, modern facility two blocks from the Seamans Center for the Engineering Arts and Sciences, and in Van Allen Hall. Current research topics are optical and electronic properties of semiconductors, semiconductor devices, electro-optics, nonlinear optics, nonlinear wave propagation in plasmas, nanotechnology, and medical devices.

Much work is done in collaboration with other University of Iowa departments, including the Departments of Physics and Astronomy, Chemistry, Internal Medicine, and Neurosurgery. Facilities include two molecular beam epitaxy reactors (in physics and astronomy), a microfabrication laboratory with micrometer resolution capabilities, electrical characterization capability to 22 GHz, several Ti-sapphire lasers, a mid-infrared optical parametric oscillator, and plasma equipment for nonlinear wave plasma interaction studies.

Examples of current projects are the design and fabrication of diode lasers based on the bandgap engineering of antimony and arsenic-based III-V compound semiconductors, phase control of laser arrays, development of an all-optical power equalizer, characterization of quantum well devices, nonlinear waveguide devices, development of a noncontact method to measure transport properties, plasma and optical soliton excitation and propagation, development of cellular probes, and a noninvasive glucose sensor for medical research.

Wireless Communication Systems

The department is engaged in research using wireless sensor networks (WSNs), which consist of spatially distributed

autonomous devices that use sensors to cooperatively monitor physical or environmental conditions such as temperature, sound, vibration, pressure, motion, and pollutants at different locations. WSNs are used for environment and habitat monitoring, health care applications, home automation, and traffic control. Current research includes the application of WSN, traditional telemetry, and commercial cellular communication infrastructure for geosciences data collection (e.g., rainfall, water quality, soil moisture).

Another important research interest involving distributed sensor networks is the distributed control of power systems, especially requirements of the next-generation electric grid with smart metering and distributed generation using small-scale wind and solar generators. Research on WSNs also includes the design of cooperative communication techniques for energy efficient WSNs and issues of localization, network organization, and control.

Research activities in communication systems focus on design and analysis of receivers for digital wireless communications, especially the development of effective and practical receivers for multiple-user wireless cellular systems in multipath channels. Projects include the removal of intersymbol interference by blind identification/equalization, multiple-user detection in CDMA without power control, receiver structures for 3G wireless cellular systems, cooperative beam forming for ad hoc wireless networks, resource allocation in OFDM systems, and scheduling in wireless networks. Fundamental theoretical issues and practical implementation are emphasized.

Facilities

Undergraduate Core

Electrical and computer engineering provides core instruction for the college in electrical circuits, electronics, instrumentation, and computers. A key part of this core teaching responsibility lies in providing students with an early opportunity to use engineering laboratory instrumentation.

Undergraduate Laboratories

The department's undergraduate laboratories include facilities for the study of electrical and electronic circuits, wireless communication, power and sustainable energy, signals and systems, microprocessor-based computers and systems, measurement automation, communication systems, control systems, computer-aided design of VLSI circuits, image processing, robotics, and optics. The laboratories are equipped with modern equipment, including digital oscilloscopes, computer-controlled virtual instrumentation, and software and hardware for embedded-systems development.

Graduate Facilities and Laboratories

The department has laboratories intended primarily for graduate research in the areas of bioinformatics, image processing, software engineering, electro-optics, control systems, medical imaging and image analysis, large-scale intelligent systems, and wireless communication. Linux and Windows workstations and server nodes provide college-wide networked computing support. Through cooperative arrangements, advanced computing facilities at national supercomputing centers, federal laboratories, and other universities are available for graduate research.

Courses

Electrical and Computer Engineering Courses

ECE:0000 Electrical Engineering Internship/Co-op 0 s.h.
Electrical engineering students participating in the Cooperative Education Program register in this course during work assignment periods; registration provides a record of participation in the program on the student's permanent record. Requirements: admission to Cooperative Education Program.

ECE:2120 Art and Engineering   3 s.h.
Collaborative, interdisciplinary, cutting-edge opportunity to gain real world engineering experience while learning to think creatively and analytically to create engaging works of art; interdisciplinary collaboration and creative methodologies that enhance life-long creative practice of artists and engineers; basic electronics and Arduino prototyping platform to create programmable, sensor-driven, responsive circuits. Prerequisites: MTLS:2910 or CERM:2010 or SCLP:2810 or TDSN:2210. Same as TDSN:2205.

ECE:2400 Linear Systems I   3 s.h.
Introduction to continuous and discrete time signals and systems with emphasis on Fourier analysis; examples of signals and systems; notion of state and finite state machines; causality; linearity and time invariance; periodicity; Fourier transforms; frequency response; convolution; IIR and FIR filters, continuous and discrete Fourier transforms; sampling and reconstruction; stability. Prerequisites: ENGR:2120 and MATH:2560.

ECE:2410 Principles of Electronic Instrumentation 4 s.h.
Principles of analog signal amplification, signal conditioning, filtering; operational amplifier circuit analysis and design; principles of operation of diodes, bipolar transistors, field effect transistors; discrete transistor amplifier analysis and design; laboratory included. Prerequisites: ENGR:2120 and PHYS:1612.

ECE:3000 Professional Seminar: Electrical Engineering   1 s.h.
Professional aspects of electrical engineering presented through lectures and discussions by guest speakers, field trips, films, panel discussions. Requirements: junior standing.

ECE:3320 Introduction to Digital Design   3 s.h.
Modern design and analysis of digital switching circuits; combinational logic; sequential circuits and system controllers; interfacing and busing techniques; design methodologies using medium- and large-scale integrated circuits; lab arranged. Requirements: sophomore standing.

ECE:3330 Introduction to Software Design   3 s.h.
Design of software for engineering systems; algorithm design and structured programming; data structures; introduction to object-oriented programming in JAVA; applications to engineering problems; lab arranged. Prerequisites: ENGR:2730. Same as IGPI:3330.

ECE:3350 Computer Architecture and Organization　　　**3 s.h.**
Basic concepts; computer evolution, register transfer level design, simulation techniques, instruction sets (CISC and RISC), assembly language programming, ALU design, arithmetic algorithms and realization of arithmetic functions, hardwired and microprogrammed control, memory hierarchies, virtual memory, cache memory, interrupts and DMA, input/output; introduction to high-performance techniques, pipelining, multiprocessing; introduction to hardware description languages (Verilog, VHDL); students design and simulate a simple processor. Prerequisites: ENGR:2730 and ECE:3320.

ECE:3360 Embedded Systems　　　**3 s.h.**
Microprocessors and microcontrollers as components in engineering systems; embedded system design processes; microcontroller/microprocessor architecture; interrupts and traps; memory and device interfacing; low-level and high-level software design for embedded systems; examples of embedded system architecture and design; fundamentals of operating systems; tasks and processes; context switching and scheduling; memory and file management, interprocess communication; device drivers. Prerequisites: ENGR:2730.

ECE:3400 Linear Systems II　　　**3 s.h.**
Continuation of ECE:2400, emphasis on Laplace and Z-transform analysis; unilateral and bilateral Laplace transform; region of convergence; stability; block diagram algebra; first- and second-order continuous and discrete time systems; Bode plots. Prerequisites: ECE:2400.

ECE:3410 Electronic Circuits　　　**4 s.h.**
Design and analysis of FET and BJT amplifiers; low, midrange, high-frequency analysis; difference amplifiers; feedback amplifiers; SPICE simulation; power amplifiers; digital logic families. Prerequisites: ECE:2410 and ECE:2400.

ECE:3500 Communication Systems　　　**3 s.h.**
Introduction to analog and digital communications, with an emphasis on modulation and noise analysis; Fourier analysis, probability theory, random variable and processes, AM, FM, pulse-coded modulation, binary digital modulation, SNR analysis of AM and FM, BER analysis of digital modulation schemes. Prerequisites: ECE:3400.

ECE:3540 Communication Networks　　　**3 s.h.**
Communication networks, layered network architectures, applications, network programming interfaces (e.g., sockets), transport, congestion, routing, data link protocols, local area networks, emerging high-speed networks, multimedia networks, network security, Internet protocol; technology examples. Prerequisites: ENGR:2730. Corequisites: STAT:2020.

ECE:3600 Control Systems　　　**3 s.h.**
Fundamental concepts of linear feedback control, mathematical modeling, transfer functions, system response, feedback effects, stability, root-locus and frequency response analysis and design, compensation, lab arranged. Prerequisites: ECE:2400.

ECE:3700 Electromagnetic Theory　　　**3 s.h.**
Electric and magnetic forces, Maxwell's equations, wave propagation; applications, including radiation, transmission lines, circuit theory. Prerequisites: MATH:3550 and PHYS:1612.

ECE:3720 Semiconductor Devices　　　**3 s.h.**
Fundamentals of semiconductor physics and devices; principles of the p-n junction diode, bipolar transistor, field effect transistor. Prerequisites: ECE:3410 and PHYS:1612.

ECE:3998 Individual Investigations: Electrical Engineering　　　**arr.**
Individual projects for electrical engineering undergraduate students: laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research.

ECE:4480 Knowledge Discovery　　　**3 s.h.**
Knowledge discovery process, including data reduction, cleansing, transformation; advanced modeling techniques from classification, prediction, clustering, association; evaluation and integration. Same as CS:4480, MSCI:4480.

ECE:4720 Introductory Optics　　　**3 s.h.**
Geometrical and physical optics; interference; diffraction; polarization; microscopic origins of macroscopic optical properties of matter; optical activity; electro-optical, magneto-optical, acousto-optical phenomena; spontaneous Brillioun, Raman, Rayleigh scattering. Prerequisites: (PHYS:1512 or PHYS:2703 or PHYS:1612) and (MATH:1560 or MATH:1860). Same as PHYS:4720.

ECE:4728 Introductory Solid State Physics　　　**3 s.h.**
Phenomena associated with solid state; classification of solids and crystal structures, electronic and vibrational properties in solids; thermal, optical, magnetic, dielectric properties of solids. Prerequisites: PHYS:3741. Same as PHYS:4728.

ECE:4880 Principles of Electrical and Computer Engineering Design　　　**3 s.h.**
Design problems requiring integration of subject matter from other required electrical and computer engineering courses. Prerequisites: ECE:2410 and ENGR:2730. Requirements: senior standing.

ECE:4890 Senior Electrical and Computer Engineering Design　　　**3 s.h.**
Individual or team project; demonstration of completed project and formal engineering report. Prerequisites: ECE:4880. Requirements: completion of three required subprogram courses.

ECE:5000 Graduate Seminar: Electrical and Computer Engineering　　　**0 s.h.**
Presentation and discussion of recent advances and research in electrical and computer engineering by guest lecturers, faculty, students. Requirements: graduate standing.

ECE:5129 Information Systems for Resource Management　　　**3 s.h.**
Understanding and managing natural and engineered resources requiring data-reach foundation; management of data; complex data-driven technologies integrated into data and information systems (DIS); hands-on opportunity to develop or use capabilities of DIS for study or research area of interest (science, engineering, industrial operation); wind power generation, an emerging field in Iowa, used as a case study for illustrating key DIS components, links, and functionalities. Same as CEE:5129, GEOG:5129, IE:5129, ME:5129.

ECE:5210 Bioinformatics Techniques　　　**3 s.h.**
Informatics tools and techniques applied to modern problems in biomedicine and basic life sciences; common tools, experience applying tools in contemporary problem settings; genomics and genetics, how to sequence a genome, transcription and expression, SNPs, Perl, BioPerl, Perl modules, Ensembl API, BLAST/BLAT, NCBI, UCSC, Ensembl Genome browsers, linkage, association, disease gene identification. Prerequisites: BIOL:1411 and (ENGR:2730 or CS:2110 or CS:5110). Same as BME:5320, IGPI:5321.

ECE:5220 Computational Genomics   **3 s.h.**
Introduction to computational methods used in genome analysis and functional genomics; biological sequence analysis, sequence database search, microarray data analysis, biological network analysis; in-depth coverage of principal genome science challenges and recent solutions. Prerequisites: (BIOS:4120 or STAT:3510) and BME:5320 and (CS:5110 or ENGR:1300). Same as BIOL:5320, BME:5330, GENE:5173, IGPI:5330.

ECE:5300 Switching Theory   **3 s.h.**
Switching algebras; combinational circuits—hazards, minimization, multiple-output networks; sequential circuits—critical races, essential hazards, fundamental-mode, pulse-mode, synchronous circuits-state assignment, state reduction; input-output experiments. Prerequisites: ECE:3320.

ECE:5310 Introduction to VLSI Design   **3 s.h.**
MOS devices and circuits; MOS transistor theory, MOS processing technologies, MOS device models; timing and power considerations; performance issues; scaling; various logic schemes; circuit techniques; clocking strategies; I/O structures; design styles; ASIC design; MOS subsystem design; system case studies, use of electronic design automation tools, introduction to hardware description languages, design synthesis, design projects; lab. Prerequisites: ECE:3320 and ECE:3410.

ECE:5320 High Performance Computer Architecture   **3 s.h.**
Problems involved in designing and analyzing current machine architectures using hardware description language (HDL) simulation and analysis, hierarchical memory design, pipeline processing, vector machines, numerical applications, multiprocessor architectures and parallel algorithm design techniques; evaluation methods to determine relationship between computer design and design goals. Prerequisites: ECE:3350 or CS:3620. Same as CS:5610.

ECE:5330 Graph Algorithms and Combinatorial Optimization   **3 s.h.**
Combinatorial optimization problems; time complexity; graph theory and algorithms; combinatorial optimization algorithms; complexity theory and NP-completeness; approximation algorithms; greedy algorithms and matroids. Prerequisites: ECE:3330. Same as IGPI:5331.

ECE:5380 Testing Digital Logic Circuits   **3 s.h.**
Logic models for faults; fault detection in combinational and sequential circuits; fault-diagnosis; design for testability; random testing, compressed data testing, built-in testing. Prerequisites: ECE:3320.

ECE:5410 Advanced Circuit Techniques   **3 s.h.**
Advanced circuit principles; component, signal and noise models; sub-circuit design including oscillators, amplifiers, multipliers, noise generators, frequency converters, phase-locked loops, filters, transmission gates and level-shifters; measurement techniques including bridge, signal averaging and lock-in techniques, case studies of A/D and D/A converters, single-supply op amps, low-noise, large-signal and high frequency circuits; lab. Prerequisites: ECE:3410.

ECE:5420 Power Electronics   **3 s.h.**
Fundamental concepts and design techniques of power electronics circuits; switching power pole and various switch-mode DC to DC power conversion topologies; feedback control of switch-mode DC to DC power supplies; diode rectification of AC utility power and Power Factor Control (PFC) circuits; electromagnetic concepts and design of high-frequency inductors and transformers; electrically isolated switch-mode DC power supply topologies and soft-switching DC-DC converters and inverters; techniques for synthesis of DC and low-frequency AC sinusoidal voltages. Prerequisites: PHYS:1611 and ENGR:2120. Requirements: junior standing.

ECE:5430 Electric Drive Systems   **3 s.h.**
Basic characteristics of DC and AC electric motors and their associated power electronics interfaces; applications of electric machines and drives that are essential for wind turbines, electric and hybrid-electric; emphasis on vehicles; electric machines in context of overall drives and associated applications; space-vector theory used to analyze electric machines and drives; DC motor/generator characteristics and control; AC single phase and three-phase motor characteristics and feedback control, including AC synchronous and induction motors. Prerequisites: ENGR:2120 and PHYS:1611. Requirements: junior standing.

ECE:5450 Pattern Recognition   **3 s.h.**
Mathematical foundations and practical techniques of pattern recognition; adaptation, learning, description; statistical pattern recognition; syntactic pattern recognition, neural networks for recognition; fuzzy logic for recognition; nonstandard and combined pattern recognition approaches. Prerequisites: ECE:2400. Same as IGPI:5450.

ECE:5460 Digital Signal Processing   **3 s.h.**
Theory, techniques used in representing discrete-time signals; system concepts in frequency and sampling domains; FIR and IIR digital filter theory, design and realization techniques; theory, application of discrete Fourier transforms/FFT. Prerequisites: ECE:3400. Same as IGPI:5460.

ECE:5480 Digital Image Processing   **3 s.h.**
Mathematical foundations and practical techniques for digital manipulation of images; image sampling, compression, enhancement, linear and nonlinear filtering and restoration; Fourier domain analysis; image pre-processing, edge detection, filtering; image segmentation. Prerequisites: ECE:2400 or BME:2200. Same as BME:5220, IGPI:5480.

ECE:5500 Communication Theory   **3 s.h.**
Random processes, source coding, digital transmission at baseband, optimum receiver design for Gaussian noise, error probability and power spectrum analysis, signal design for bandlimited channels, digital carrier modulation, bandwidth/energy/error probability tradeoffs, coding for error detection and correction. Prerequisites: STAT:2020 and ECE:3500.

ECE:5520 Introduction to Information and Coding Theories   **3 s.h.**
Quantitative measure of information; source encoding; error detecting codes; block and convolutional codes, design of hardware and software implementations; Viterbi decoding. Prerequisites: ECE:3500 and STAT:2020.

ECE:5530 Wireless Sensor Networks   3 s.h.
Wireless senor networks overview; antennas, radio propagation models; WSN power and energy considerations, engineering issues, batteries, networks layers, stacks; medium access control (MAC); spread spectrum, FHSS, CDMA; infrastructure establishment; WSN routing; localization; synchronization; sensors; RFID; WSN case studies; lab. Prerequisites: STAT:2020 and ECE:3500. Requirements: senior standing.

ECE:5550 Internet of Things   3 s.h.
Internet of Things (IoT) describes the evolution of the Internet to intelligent devices, sensors, actuators, controllers, and other types of Internet-enabled components; soon, IoT-based applications will enable seminal advances in a wide range of areas including health and lifestyle, transportation, smart cities, environment, energy, agriculture, and industry; topics include IoT logical and physical structure, IoT-enabled Internet services, IoT devices/platforms/endpoints, IoT application domains, IoT security and privacy issues, and IoT data analytic; case studies and projects focused on design and implementation of a working IoT application. Prerequisites: ENGR:2730. Requirements: background in computer networks or embedded systems.

ECE:5600 Control Theory   3 s.h.
State space approach; controllability, observability, canonical forms, Luenberger observers, feedback control via pole placement, stability, minimal realization and optimal control. Prerequisites: ECE:3600. Same as ME:5360.

ECE:5620 Electric Power Systems   3 s.h.
Overview of electric power systems; single phase and three-phase representations of electric power signals and electromagnetic concepts; AC transmission lines and underground cables, power flow in a power system network, AC power transformers, High Voltage DC (HVDC) power transmission, electric power distribution, synchronous generators, voltage regulation and stability, power system transients and dynamic stability, control of interconnected power systems, transmission line faults, transient over-voltages and surge protection. Prerequisites: PHYS:1611 and ENGR:2120. Requirements: junior standing.

ECE:5630 Sustainable Energy Conversion   3 s.h.
Overview of sustainable energy conversion technologies; thermal energy conversion; Carnot and Rankine cycles; solar resource and raw energy availability, PV solar cell characteristics, solar panel construction, Maximum Power Point (MPP) tracking and utility grid interface; wind energy conversion resource and available energy, wind turbine configurations, electrical power interface electronics; ocean energy conversion tidal and wave resources and conversion technologies; tidal basin containment conversion and tidal current turbine systems. Prerequisites: ENGR:2120 and PHYS:1611. Requirements: junior standing.

ECE:5640 Computer-Based Control Systems   3 s.h.
Discrete and digital control systems; application of computers in control; sampling theorem; discrete time system models; analysis and design of discrete time systems; control design by state variable and input/output methods; advanced topics in digital controls; lab. Prerequisites: ECE:5600. Same as IGPI:5641, ME:5362.

ECE:5700 Advanced Electromagnetic Theory   3 s.h.
Time varying fields; plane wave propagation, reflection, refraction; waves in anisotropic media transmission lines, impedance matching, Smith chart; metallic and dielectric wave guides; resonators; antennas, antenna arrays. Prerequisites: ECE:3700.

ECE:5720 Solid State Physical Electronics   3 s.h.
Advanced topics in semiconductor physics and devices; elementary concepts in quantum and statistical mechanics, diodes, bipolar transistor, field-effect transistor. Prerequisites: ECE:3720.

ECE:5780 Optical Signal Processing   3 s.h.
Linear systems description of optical propagation; diffraction and angular plane wave spectrum; lenses as Fourier transformers, lens configurations as generalized optical processors; lasers, coherence, spatial frequency analysis; holography; convolvers, correlators, matched filters; synthetic aperture radar; optical computing. Requirements: for ECE:5780—ECE:3700; for PHYS:4820—PHYS:3812. Same as PHYS:4820.

ECE:5790 Electro Optics   3 s.h.
Wave equation solutions; optical birefringence; finite beam propagation in free space, dielectric waveguides and fibers; optical resonators; nonlinear phenomena; electro-optic, acousto-optic modulation; optical detection, noise; application to communication systems. Requirements: for ECE:5790—ECE:3700; for PHYS:4726—PHYS:3812. Same as PHYS:4726.

ECE:5800 Fundamentals of Software Engineering 3 s.h.
Problem analysis, requirements definition, specification, design, implementation, testing/maintenance, integration, project management; human factors; management, technical communication; design methodologies; software validation, verification; group project experience. Prerequisites: CS:2820 or ECE:3330. Same as CS:5800.

ECE:5810 Formal Methods in Software Engineering   3 s.h.
Models, methods, and their application in all phases of software engineering process; specification methods; verification of consistency, completeness of specifications; verification using tools. Prerequisites: ECE:3330 or CS:2820. Recommendations: CS:4350. Same as CS:5810.

ECE:5820 Software Engineering Languages and Tools   3 s.h.
Modern agile software development practices for cloud and web-based applications, using state-of-the-art software engineering languages, tools, and technologies; agile software development practices, software-as-a-service (SAAS), and the Ruby on Rails Development Framework. Requirements: ECE:5800 or CS:5800; or graduate standing with solid understanding of object-oriented design and programming, and facility with at least one object-oriented programming language. Same as CS:5820.

ECE:5830 Software Engineering Project   3 s.h.
Team software development project using concepts and methodologies learned in earlier software engineering classes; practical aspects of large-scale software development. Prerequisites: ECE:5820 and CS:5800. Same as CS:5830.

ECE:5995 Contemporary Topics in Electrical and Computer Engineering   arr.
New topics or areas of study not offered in other electrical and computer engineering courses; based on faculty/student interest; not available for individual study. Prerequisites: ECE:2400 and STAT:2020.

ECE:5998 Individual Investigations: Electrical and Computer Engineering   arr.
Individual projects for electrical and computer engineering graduate students; laboratory study, engineering design project, analysis and simulation of an engineering system, computer software development, research. Requirements: graduate standing.

ECE:5999 Research: Electrical and Computer Engineering M.S. Thesis arr.
Experimental and/or analytical investigation of approved topic for partial fulfillment of requirements for M.S. degree with thesis in electrical and computer engineering. Requirements: graduate standing.

ECE:6720 Nonlinear Optics 3 s.h.
Classical treatment of second- and third-order optical nonlinearities; phase matching, harmonic generation, three- and four-wave mixing, self-focusing, self-phase modulation, stimulated scattering of light, applications. Requirements: for PHYS:6720—PHYS:3812; for ECE:6720—ECE:5700 or PHYS:3812. Same as PHYS:6720.

ECE:6726 Laser Principles 3 s.h.
Laser theory, stimulated emission, dispersion theory, broadening mechanisms, rate equations, gain saturation, optical resonators, mode-locking, Q-switching techniques, survey of laser types, modes of operation. Requirements: for PHYS:6726—PHYS:3812; for ECE:6726—ECE:5700. Same as PHYS:6726.

ECE:7450 Magnetic Resonance Imaging Systems 3 s.h.
Mathematical foundations and practical implementation for magnetic resonance imaging (MRI); principles of image formation using Fourier and projection techniques, non-Cartesian sampling, tomographic image reconstruction, sources of artifacts and their correction. Prerequisites: ECE:5460 and ECE:5480. Same as IGPI:7450.

ECE:7470 Image Analysis and Understanding 3 s.h.
Mathematical foundations and practical techniques of digital image analysis and understanding; image segmentation (from edges and regions), object description (from boundaries, regions, scale, scale insensitive descriptions, 3-D shape, texture) pattern recognition (statistical and syntactic methods, cluster analysis), image understanding (knowledge representation, control strategies, matching, context, semantics), image analysis and understanding systems; lab arranged. Prerequisites: ECE:5480. Same as IGPI:7470.

ECE:7480 Advanced Digital Image Processing 3 s.h.
Advanced local operators (scale-space imaging, advanced edge detection, line and corner detection), image morphology (binary/gray scale operators, morphological segmentation and watershed), digital topology and geometry (binary/fuzzy digital topology, distance functions, skeletonization), color spaces, wavelets and multi-resolution processing (Haar transform, multi-resolution expansions, wavelet transforms in one or two dimensions, fast wavelet transform, wavelet packets), image registration (intensity correlation, mutual information, and landmark-based deformable registration methods). Prerequisites: ECE:5460 and ECE:5480. Same as IGPI:7480.

ECE:7720 Semiconductor Physics 3 s.h.
Electronic, optical, and materials properties of semiconductors. Prerequisites: PHYS:4728 and PHYS:5742. Same as PHYS:7720.

ECE:7920 ECE Graduate Seminar on Image Processing, Computer Vision and Medical Imaging 0 s.h.
Recent advances and research in image processing, computer vision, and medical imaging; presentation by guest lecturers, faculty, students. Requirements: graduate standing.

ECE:7930 Seminar: Plasma Physics arr.
Current research. Same as PHYS:7930.

ECE:7995 Advanced Topics in Electrical and Computer Engineering arr.
Discussion of current literature in electrical and computer engineering.

ECE:7999 Research: Electrical and Computer Engineering Ph.D. Thesis arr.
Experimental and/or analytical investigation of approved topic for partial fulfillment of requirements for Ph.D. in electrical and computer engineering.