ELECTRICAL, COMPUTER, AND SYSTEMS ENGINEERING (ECSE)

ECSE 132. Programming in Java. 3 Units.

An in-depth survey of modern programming language features, computer programming and algorithmic problem solving with an emphasis on the Java language. Computers and code compilation; conditional statements, subprograms, loops, methods; object-oriented design, inheritance and polymorphism, abstract classes and interfaces; types, type systems, generic types, abstract data types, strings, arrays, linked lists; software development, modular code design, unit testing; strings, text and file I/ O; GUI components, GUI event handling; threads; comparison of Java to C, C++, and C#. Offered as CSDS 132 and ECSE 132. Counts as a CAS Quantitative Reasoning course.

ECSE 216. Fundamental System Concepts. 3 Units.

Develops framework for addressing problems in science and engineering that require an integrated, interdisciplinary approach, including the effective management of complexity and uncertainty. Introduces fundamental system concepts in an integrated framework. Properties and behavior of phenomena regardless of the physical implementation through a focus on the structure and logic of information flow. Systematic problem solving methodology using systems concepts. Recommended preparation: MATH 224.

ECSE 233. Introduction to Data Structures. 4 Units.

Different representations of data: lists, stacks and queues, trees, graphs, and files. Manipulation of data: searching and sorting, hashing, recursion and higher order functions. Abstract data types, templating, and the separation of interface and implementation. Introduction to asymptotic analysis. The Java language is used to illustrate the concepts and as an implementation vehicle throughout the course. Offered as CSDS 233 and ECSE 233. Prereq: ECSE 132.

ECSE 245. Electronic Circuits. 4 Units.

Analysis of time-dependent electrical circuits. Dynamic waveforms and elements: inductors, capacitors, and transformers. First- and secondorder circuits, passive and active. Analysis of sinusoidal steady state response using phasors. Laplace transforms and pole-zero diagrams. S-domain circuit analysis. Two-port networks, impulse response, and transfer functions. Introduction to nonlinear semiconductor devices: diodes, BJTs, and FETs. Gain-bandwidth product, slew-rate and other limitations of real devices. SPICE simulation and laboratory exercises reinforce course materials. Prereq: ENGR 210. Prereq or Coreq: MATH 224.

ECSE 246. Signals and Systems. 4 Units.

Mathematical representation, characterization, and analysis of continuous-time signals and systems. Development of elementary mathematical models of continuous-time dynamic systems. Time domain and frequency domain analysis of linear time-invariant systems. Fourier series, Fourier transforms, and Laplace transforms. Sampling theorem. Filter design. Introduction to feedback control systems and feedback controller design. Prereq: ENGR 210. Prereq or Coreq: MATH 224.

ECSE 275. Fundamentals of Robotics. 4 Units.

The Fundamentals of Robotics course will expose students to fundamental principles of robotics. Students will explore high level conceptual foundations of robotics beginning with Braitenberg vehicles and apply this knowledge to simulated and physical robot hardware in laboratory experiences and in a final project. Laboratory experiences will guide students through applying theory to practice increasingly complex tasks in a project oriented, group work environment. The course culminates in a robotics challenge project at the end of the semester. Topics covered are: sensors, actuators, kinematics, control, planning and programming. Programming languages and concepts (e.g., C++, object oriented programming) used in robotics will be introduced and used with modern robotics programming toolboxes and frameworks. Prior experience with these languages will not be necessary. Previous experience with robotics is not required for this course. Offered as CSDS 275 and ECSE 275. Prereq: (ENGR 130 or ENGR 131 or ECSE 132) and PHYS 121 and MATH 121.

ECSE 281. Logic Design and Computer Organization. 4 Units.

Fundamentals of digital systems in terms of both computer organization and logic level design. Organization of digital computers; information representation; boolean algebra; analysis and synthesis of combinational and sequential circuits; datapaths and register transfers; instruction sets and assembly language; input/output and communication; memory. Offered as CSDS 281 and ECSE 281. Prereq: ENGR 130 or ENGR 131 or ECSE 132.

ECSE 290. Introduction to Computer Game Design and Implementation. 3 Units.

This class begins with an examination of the history of video games and of game design. Games will be examined in a systems context to understand gaming and game design fundamentals. Various topics relating directly to the implementation of computer games will be introduced including graphics, animation, artificial intelligence, user interfaces, the simulation of motion, sound generation, and networking. Extensive study of past and current computer games will be used to illustrate course concepts. Individual and group projects will be used throughout the semester to motivate, illustrate and demonstrate the course concepts and ideas. Group game development and implementation projects will culminate in classroom presentation and evaluation. Offered as CSDS 290 and ECSE 290. Prereq: ECSE 132.

ECSE 301. Digital Logic Laboratory. 2 Units.

This course is an introductory experimental laboratory for digital networks. The course introduces students to the process of design, analysis, synthesis and implementation of digital networks. The course covers the design of combinational circuits, sequential networks, registers, counters, synchronous/asynchronous Finite State Machines, register based design, and arithmetic computational blocks. Prereq: ECSE 281.

ECSE 302. Discrete Mathematics. 3 Units.

A general introduction to basic mathematical terminology and the techniques of abstract mathematics in the context of discrete mathematics. Topics introduced are mathematical reasoning, Boolean connectives, deduction, mathematical induction, sets, functions and relations, algorithms, graphs, combinatorial reasoning. Offered as CSDS 302, ECSE 302 and MATH 304. Prereq: MATH 122 or MATH 124 or MATH 126.

ECSE 303. Embedded Systems Design and Laboratory. 3 Units.

The purpose of this Course and Laboratory is to expose and train the students in modern embedded systems software and hardware design techniques and practices including networking and mobile connectivity. The rationale for the Course and Lab is based on the explosive growth of embedded systems in the industry, specifically industrial automation, aviation, surveillance, medical devices, but also common consumer products. The course topics cover a wide range of material as follows. Microcontroller systems based on the ARM processor. Essential components, memories, busses interfaces. Devices, peripherals, GPIOs, device drivers. Sensors and Actuators, A/D, D/A, DSP. Embedded Linux, kernels, kernel modules, compilers and assemblers. Libraries, and debugging facilities. The Lab will be based on common platforms such as Raspberry pi, Arduino, ARM embed, supported by a network of Linux workstations.

ECSE 304. Control Engineering I with Laboratory. 3 Units.

Analysis and design techniques for control applications. Linearization of nonlinear systems. Design specifications. Classical design methods: root locus, bode, nyquist. PID, lead, lag, lead-lag controller design. State space modeling, solution, controllability, observability and stability. Modeling and control demonstrations and experiments single-input/ single-output and multivariable systems. Control system analysis/ design/implementation software. The course will incorporate the use of Grand Challenges in the areas of Energy Systems, Control Systems, and Data Analytics in order to provide a framework for problems to study in the development and application of the concepts and tools studied in the course. Various aspects of important engineering skills relating to leadership, teaming, emotional intelligence, and effective communication are integrated into the course. Prereq: ECSE 246 or EMAE 350.

ECSE 305. Control Engineering I Laboratory. 1 Unit.

A laboratory course based on the material in ECSE 304. Modeling, simulation, and analysis using MATLAB. Physical experiments involving control of mechanical systems, process control systems, and design of PID controllers. Coreq: ECSE 304.

ECSE 309. Electromagnetic Fields I. 3 Units.

Maxwell's integral and differential equations, boundary conditions, constitutive relations, energy conservation and Poynting vector, wave equation, plane waves, propagating waves and transmission lines, characteristic impedance, reflection coefficient and standing wave ratio, in-depth analysis of coaxial and strip lines, electro- and magnetoquasistatics, simple boundary value problems, correspondence between fields and circuit concepts, energy and forces. Prereq: PHYS 122 or PHYS 124. Prereq or Coreq: MATH 224.

ECSE 313. Signal Processing. 3 Units.

Fourier series and transforms. Analog and digital filters. Fast-Fourier transforms, sampling, and modulation for discrete time signals and systems. Consideration of stochastic signals and linear processing of stochastic signals using correlation functions and spectral analysis. The course will incorporate the use of Grand Challenges in the areas of Energy Systems, Control Systems, and Data Analytics in order to provide a framework for problems to study in the development and application of the concepts and tools studied in the course. Various aspects of important engineering skills relating to leadership, teaming, emotional intelligence, and effective communication are integrated into the course. Prereq: ECSE 246.

ECSE 314. Computer Architecture. 3 Units.

This course provides students the opportunity to study and evaluate a modern computer architecture design. The course covers topics in fundamentals of computer design, performance, cost, instruction set design, processor implementation, control unit, pipelining, communication and network, memory hierarchy, computer arithmetic, input-output, and an introduction to RISC and super-scalar processors. Offered as CSDS 314 and ECSE 314. Prereq: ECSE 281.

ECSE 315. Digital Systems Design. 4 Units.

This course gives students the ability to design modern digital circuits. The course covers topics in logic level analysis and synthesis, digital electronics: transistors, CMOS logic gates, CMOS lay-out, design metrics space, power, delay. Programmable logic (partitioning, routing), state machine analysis and synthesis, register transfer level block design, datapath, controllers, ASM charts, microsequencers, emulation and rapid protyping, and switch/logic-level simulation. Prereq: ECSE 281.

ECSE 316. Wireless Communications. 3 Units.

This course introduces the fundamentals of wireless communications including backgrounds, important concepts, and cutting-edge technologies. In particular, the course focuses on interesting and important topics in wireless communications, such as (but not limited to): Overview of wireless communication networks and protocols, the cellular concept, system design fundamentals, brief introduction to wireless physical layer fundamentals, multiple access control protocols for wireless systems, wireless networking (routing/rerouting, wireless TCP/IP), mobility management, call admission control and resource allocation, revolution/evolution towards future generation wireless networks, overview of wireless mesh networks, mobile ad hoc networks and wireless sensor networks, and wireless security (optional). Offered as ECSE 316 and ECSE 414. Prereq: ECSE 351 with a C or better or a Graduate student.

ECSE 317. Computer Design - FPGAs. 3 Units.

The aim is to expose the student to methodologies for systematic design of digital systems with emphasis on programmable logic implementations and prototyping. The course requires a number of hands-on experiments and an overall lab project. The lab involves a number of class lectures to familiarize the students with the modern design techniques based on VHDL/Verilog Hardware Design Languages, CAD tools, and FPGAs. Offered as ECSE 317 and ECSE 417. Prereq: ECSE 281.

ECSE 318. VLSI/CAD. 4 Units.

With Very Large Scale Integration (VLSI) technology there is an increased need for Computer-Aided Design (CAD) techniques and tools to help in the design of large digital systems that deliver both performance and functionality. Such high performance tools are of great importance in the VLSI design process, both to perform functional, logical, and behavioral modeling and verification to aid the testing process. This course discusses the fundamentals in behavioral languages, both VHDL and Verilog, with hands-on experience. Prereq: ECSE 281 and ECSE 315.

ECSE 319. Applied Probability and Stochastic Processes for Biology. 3 Units.

Applications of probability and stochastic processes to biological systems. Mathematical topics will include: introduction to discrete and continuous probability spaces (including numerical generation of pseudo random samples from specified probability distributions), Markov processes in discrete and continuous time with discrete and continuous sample spaces, point processes including homogeneous and inhomogeneous Poisson processes and Markov chains on graphs, and diffusion processes including Brownian motion and the Ornstein-Uhlenbeck process. Biological topics will be determined by the interests of the students and the instructor. Likely topics include: stochastic ion channels, molecular motors and stochastic ratchets, actin and tubulin polymerization, random walk models for neural spike trains, bacterial chemotaxis, signaling and genetic regulatory networks, and stochastic predator-prey dynamics. The emphasis will be on practical simulation and analysis of stochastic phenomena in biological systems. Numerical methods will be developed using a combination of MATLAB, the R statistical package, MCell, and/or URDME, at the discretion of the instructor. Student projects will comprise a major part of the course. Offered as BIOL 319, ECSE 319, MATH 319, SYBB 319, BIOL 419, EBME 419, MATH 419, PHOL 419, and SYBB 419. Prereq: (MATH 224 or MATH 223) and (BIOL 300 or BIOL 306) and (MATH 201 or MATH 307).

ECSE 321. Semiconductor Electronic Devices. 4 Units.

Energy bands and charge carriers in semiconductors and their experimental verifications. Excess carriers in semiconductors. Principles of operation of semiconductor devices that rely on the electrical properties of semiconductor surfaces and junctions. Development of equivalent circuit models and performance limitations of these devices. Devices covered include: junctions, bipolar transistors, Schottky junctions, MOS capacitors, junction gate and MOS field effect transistors, optical devices such as photodetectors, light-emitting diodes, solar cells, and lasers. Prereq: PHYS 122. Prereq or Coreq: MATH 224.

ECSE 322. Integrated Circuits and Electronic Devices. 3 Units.

Technology of monolithic integrated circuits and devices, including crystal growth and doping, photolithography, vacuum technology, metalization, wet etching, thin film basics, oxidation, diffusion, ion implantation, epitaxy, chemical vapor deposition, plasma processing, and micromachining. Basics of semiconductor devices including junction diodes, bipolar junction transistors, and field effect transistors. Prereq: PHYS 122. Prereq or Coreq: MATH 224.

ECSE 324. Modeling and Simulation of Continuous Dynamical Systems. 3 Units.

This course examines the computer-based modeling and simulation of continuous dynamical system behavior in a variety of systems including electric power systems, industrial control systems, and signal processing that are represented by a set of differential equations need to be solved numerically in order to compute and represent their behavior for study. In addition to these applications, there are many other important applications of these tools in computer games, virtual worlds, weather forecasting, and population models, to name a few examples. Numerical integration techniques are developed to perform these computations. Multiple computational engines such as Matlab, Simulink, Unity, and physics engines etc. are also examined as examples of commonly used software to solve for and visualize continuous-time system behavior. The course will incorporate the use of Grand Challenges in the areas of Energy Systems, Control Systems, and Data Analytics in order to provide motivation and a framework for problems to study in the development and application of the concepts and tools studied in the course. Various aspects of important engineering skills relating to leadership, teaming, emotional intelligence, and effective communication are integrated into the course. Prereq: MATH 224.

ECSE 326. Instrumentation Electronics. 3 Units.

A second course in instrumentation with emphasis on sensor interface electronics. General concepts in measurement systems, including accuracy, precision, sensitivity, linearity, and resolution. The physics and modeling of resistive, reactive, self-generating, and direct-digital sensors. Signal conditioning for same, including bridge circuits, coherent detectors, and a variety of amplifier topologies: differential, instrumentation, charge, and transimpedance. Noise and drift in amplifiers and resistors. Practical issues of interference, including grounding, shielding, supply/return, and isolation amplifiers. Prereq: ENGR 210 and (ECSE 246 or EBME 308 or EMAE 350).

ECSE 337. Compiler Design. 4 Units.

Design and implementation of compilers and other language processors. Scanners and lexical analysis; regular expressions and finite automata; scanner generators; parsers and syntax analysis; context free grammars; parser generators; semantic analysis; intermediate code generation; runtime environments; code generation; machine independent optimizations; data flow and dependence analysis. There will be a significant programming project involving the use of compiler tools and software development tools and techniques. Offered as CSDS 337 and ECSE 337. Prereq: ECSE 233 and ECSE 281.

ECSE 338. Intro to Operating Systems and Concurrent Programming. 4 Units.

Intro to OS: OS Structures, processes, threads, CPU scheduling, deadlocks, memory management, file system implementations, virtual machines, cloud computing. Concurrent programming: fork, join, concurrent statement, critical section problem, safety and liveness properties of concurrent programs, process synchronization algorithms, semaphores, monitors. UNIX systems programming: system calls, UNIX System V IPCs, threads, RPCs, shell programming. Offered as CSDS 338, ECSE 338, CSDS 338N and ECSE 338N. Prereq: Computer Science Major or Minor and ECSE 233 with a C or higher.

ECSE 338N. Intro to Operating Systems and Concurrent Programming. 4 Units.

Intro to OS: OS Structures, processes, threads, CPU scheduling, deadlocks, memory management, file system implementations, virtual machines, cloud computing. Concurrent programming: fork, join, concurrent statement, critical section problem, safety and liveness properties of concurrent programs, process synchronization algorithms, semaphores, monitors. UNIX systems programming: system calls, UNIX System V IPCs, threads, RPCs, shell programming. Offered as CSDS 338, ECSE 338, CSDS 338N and ECSE 338N. Prereq: ECSE 233 with a C or higher.

ECSE 342. Introduction to Global Issues. 3 Units.

This systems course is based on the paradigm of the world as a complex system. Global issues such as population, world trade and financial markets, resources (energy, water, land), global climate change, and others are considered with particular emphasis put on their mutual interdependence. A reasoning support computer system which contains extensive data and a family of models is used for future assessment. Students are engaged in individual, custom-tailored, projects of creating conditions for a desirable or sustainable future based on data and scientific knowledge available. Students at CWRU will interact with students from fifteen universities that have been strategically selected in order to give global coverage to UNESCO'S Global-problematique Education Network Initiative (GENIe) in joint, participatory scenario analysis via the internet.

ECSE 3421. Global Issues, Health, & Sustainability in India. 3 Units.

Global Issues, Health, & Sustainability in India is an interdisciplinary social work and engineering collaboration that includes a short-term cross-cultural immersion. This course brings together social work (knowledge, values, and skills) and health care (promotion, education, and community) perspectives to the understanding of technical project assessment, selection, planning and implementation in India. The course is also designed to help students understand culturally relevant community engagement strategies to ensure project acceptance in underserved and developing communities. Many field sites will be visited in order to observe first-hand the community assessment and development of projects that engineers implement. An example of these projects could include infrastructure to support green energy and water (resource planning, development, conservation, and sanitation). This study abroad course will acquaint students with history and culture of India, its social, political and economic development and the impact it has on health and the delivery of social services. Participants will learn about factors affecting the abilities to reach, treat, educate, and equip communities to improve health outcomes. Engineering students will learn the quantitative aspects using a paradigm of hierarchical systems, mathematical modeling, and scenario analysis using a 'reasoning support' system. Together the engineering, social work, and health sciences students in disciplinary-balanced teams will jointly work on real and meaningful projects marrying the descriptive scenarios (that is the 'subjective' aspect) with the numerical scenario analysis based on mathematical modeling (or 'objective' aspect) to form a coherent view of the future. The course will be taught using both lecture and experiential modalities. Engineering students will conduct computer modeling work. Along with visiting a variety of governmental and non-governmental institutions, organizations and projects, students will visit historical sites and attend cultural events. Offered as ECSE 342I and SASS 375I. Counts as a CAS Global & Cultural Diversity course.

ECSE 344. Electronic Analysis and Design. 3 Units.

The design and analysis of real-world circuits. Topics include: junction diodes, non-ideal op-amp models, characteristics and models for large and small signal operation of bipolar junction transistors (BJTs) and field effect transistors (FETs), selection of operating point and biasing for BJT and FET amplifiers. Hybrid-pi model and other advanced circuit models, cascaded amplifiers, negative feedback, differential amplifiers, oscillators, tuned circuits, and phase-locked loops. Computers will be extensively used to model circuits. Selected experiments and/or laboratory projects. Prereq: ECSE 245.

ECSE 346. Engineering Optimization. 3 Units.

Optimization techniques including linear programming and extensions; transportation and assignment problems; network flow optimization; quadratic, integer, and separable programming; geometric programming; and dynamic programming. Nonlinear optimization topics: optimality criteria, gradient and other practical unconstrained and constrained methods. Computer applications using engineering and business case studies. The course will incorporate the use of Grand Challenges in the areas of Energy Systems, Control Systems, and Data Analytics in order to provide a framework for problems to study in the development and application of the concepts and tools studied in the course. Various aspects of important engineering skills relating to leadership, teaming, emotional intelligence, and effective communication are integrated into the course. Recommended preparation: MATH 201.

ECSE 350. Operations and Systems Design. 3 Units.

Introduction to design, modeling, and optimization of operations and scheduling systems with applications to computer science and engineering problems. Topics include, forecasting and time series, strategic, tactical, and operational planning, life cycle analysis, learning curves, resources allocation, materials requirement and capacity planning, sequencing, scheduling, inventory control, project management and planning. Tools for analysis include: multi-objective optimization, queuing models, simulation, and artificial intelligence.

ECSE 351. Communications and Signal Analysis. 3 Units.

Fourier transform analysis and sampling of signals. AM, FM and SSB modulation and other modulation methods such as pulse code, delta, pulse position, PSK and FSK. Detection, multiplexing, performance evaluation in terms of signal-to-noise ratio and bandwidth requirements. Prereq: ECSE 246 or requisites not met permission.

ECSE 352. Engineering Economics and Decision Analysis. 3 Units.

Economic analysis of engineering projects, focusing on financial decisions concerning capital investments. Present worth, annual worth, internal rate of return, benefit/cost ratio. Replacement and abandonment policies, effects of taxes, and inflation. Decision making under risk and uncertainty. Decision trees. Value of information. The course will incorporate the use of Grand Challenges in the areas of Energy Systems, Control Systems, and Data Analytics in order to provide a framework for problems to study in the development and application of the concepts and tools studied in the course. Various aspects of important engineering skills relating to leadership, teaming, emotional intelligence, and effective communication are integrated into the course.

ECSE 354. Digital Communications. 3 Units.

Fundamental bounds on transmission of information. Signal representation in vector space. Optimum reception. Probability and random processes with application to noise problems, speech encoding using linear prediction. Shaping of base-band signal spectra, correlative coding and equalization. Comparative analysis of digital modulation schemes. Concepts of information theory and coding. Applications to data communication. Prereq: ECSE 246 or requisites not met permission.

ECSE 360. Manufacturing and Automated Systems. 3 Units.

Formulation, modeling, planning, and control of manufacturing and automated systems with applications to computer science and engineering problems. Topics include, design of products and processes, location/spatial problems, transportation and assignment, product and process layout, group technology and clustering, cellular and network flow layouts, computer control systems, reliability and maintenance, and statistical quality control. Tools and analysis include: multi-objective optimization, artificial intelligence, and heuristics for combinatorial problems. Offered as ECSE 360 and ECSE 460.

ECSE 366. Computer Graphics. 3 Units.

Theory and practice of computer graphics: object and environment representation including coordinate transformations image extraction including perspective, hidden surface, and shading algorithms; and interaction. Covers a wide range of graphic display devices and systems with emphasis in interactive shaded graphics. Offered as CSDS 366, ECSE 366, CSDS 466 and ECSE 466. Prereq: ECSE 233.

ECSE 368. Power System Analysis I. 3 Units.

This course introduces the steady-state modeling and analysis of electric power systems. The course discusses the modeling of essential power system network components such as transformers and transmission lines. The course also discusses important steady-state analysis of three-phase power system network, such as the power flow and economic operation studies. Through the use of PowerWorld Simulator education software, further understanding and knowledge can be gained on the operational characteristics of AC power systems. Special topics concerning new grid technologies will be discussed towards the semester end. The prerequisite requirements of the course include the concepts and computational techniques of Alternative Current (AC) circuit and electromagnetic field. Offered as ECSE 368 and ECSE 468. Prereq: ECSE 245.

ECSE 369. Power System Analysis II. 3 Units.

This course extends upon the steady state analysis of power systems to cover study topics that are essential for power system planning and operation. Special system operating conditions are considered, such as unbalanced network operation and component faults. Among the most important analytical methods developed, are symmetrical components and sequence networks. Other study topics discussed include the electric machine modeling and power system transient stability. The latter half of the course presents computational methods and control algorithms that are essential for power system operation, such as generation control and state estimation. Offered as ECSE 369 and ECSE 469. Prereq: ECSE 368.

ECSE 371. Applied Circuit Design. 4 Units.

This course will consist of lectures and lab projects designed to provide students with an opportunity to consolidate their theoretical knowledge of electronics and to acquaint them with the art and practice of circuit and product design. The lectures will cover electrical and electronic circuits and many electronic and electrical devices and applications. Examples include mixed-signal circuits, power electronics, magnetic and piezo components, gas discharge devices, sensors, motors and generators, and power systems. In addition, there will be discussion of professional topics such as regulatory agencies, manufacturing, testing, reliability, and product cost. Weekly labs will be true "design" opportunities representing real-world applications. A specification or functional description will be provided, and the students will design the circuit, select all components, construct a breadboard, and test. The objective will be functional, pragmatic, cost-effective designs. Offered as ECSE 371 and ECSE 471. Prereq: ECSE 344.

ECSE 373. Modern Robot Programming. 3 Units.

The goal of this course is to learn modern methods for building up robot capabilities using the Robot Operating System (ROS). Through a sequence of assignments, students learn how to write software to control both simulated and physical robots. Material includes: interfacing software to robot I/O; path and trajectory planning for robot arms; object identification and localization from 3-D sensing; manipulation planning; and development of graphical interfaces for supervisory robot control. Laboratory assignments are scheduled in small groups to explore implementations on specific robots. Graduate students will also perform an independent project. Offered as CSDS 373, ECSE 373, CSDS 473 and ECSE 473. Prereq: ENGR 130 or ENGR 131 or ECSE 132.

ECSE 374. Advanced Control and Energy Systems. 3 Units.

This course introduces applied quantitative robust and nonlinear control engineering techniques to regulate automatically renewable energy systems in general and wind turbines in particular. The course also studies the fundamentals for dynamic multidisciplinary modeling and analysis of large multi-megawatt wind turbines (mechanics, aerodynamics, electrical systems, control concepts, etc.). The course combines lecture sessions and lab hours. The 400-level includes an experimental lab competition, where the object is to design, implement, and experimentally validate a control strategy to regulate a real system in the laboratory (helicopter control competition or similar); it will also include additional project design reports. Offered as ECSE 374 and ECSE 474. Prereq: ECSE 304.

ECSE 375. Applied Control. 3 Units.

This course provides a practical treatment of the study of control engineering systems. It emphasizes best practices in industry so that students learn what aspects of plant and control system design are critical. The course develops theory and practice for digital computer control systems; PID controller design (modes, forms and tuning methods); Control structure design (feed-forward, cascade control, predictive control, disturbance observers, multi-loop configurations, multivariable control); Actuators, sensors and common loops; Dynamic performance evaluation; and some advanced control techniques (quantitative robust control, gain-scheduling and adaptive control) to achieve a good performance over a range of operating conditions. Recommended preparation: ECSE 374 or ECSE 474. Offered as ECSE 375 and ECSE 475. Prereq: ECSE 304 or Requisites Not Met permission.

ECSE 376. Mobile Robotics. 4 Units.

Design of software systems for mobile robot control, including: motion control; sensory processing; localization and mapping; mobile-robot planning and navigation; and implementation of goal-directed behaviors. The course has a heavy lab component involving a sequence of design challenges and competitions performed in teams. Offered as CSDS 376 and ECSE 376. Prereq: ECSE 373 or ECSE 473.

ECSE 377. Introduction to Connected Devices. 3 Units.

Introduction to Connected Devices (e.g., Internet of Things). Undergraduates work in pairs to build a complete connected-device system, an embedded device with wireless networking, cloud and web, and mobile, and then develop hands-on experience with systems-level aspects of the connected-device system, including analytics, remote firmware update, load testing, and essential security. Students learn about current architectures, languages, and technologies, such as Pub/ Sub (MQTT), Python, Objective-C, Python Django, JavaScript, HTML/CSS, and Bluetooth Low Energy. Offered as CSDS 377 and ECSE 377.

ECSE 386. Quantum Computing, Information, and Devices. 3 Units.

An introduction to the math, physics, engineering, and computer science underlying the rapidly emerging fields of quantum computing, quantum information, and quantum devices. The course is taught by a group of faculty from physics, engineering, computer science, and math, and is geared towards students with diverse backgrounds and interests in these fields. Students will select a concentration in one of these four areas, and the coursework, while still covering all topics, will be adjusted to focus on the selected area in the most detail. Note that the listed prerequisites depend on choice of concentration. Topics will include: 1. (Mathematics) Introduction to linear algebra, convex geometry, fundamental theory of quantum information. 2. (Physics) Introduction to the quantum mechanics of two-level systems (qubits). Survey of physics and materials for qubit technologies. 3. (Computer Science) Basic quantum gates and circuits, introduction to the theory of algorithms, survey of quantum algorithms. 4. (Engineering) Quantum architectures, mapping algorithms onto circuits. The course consists of lectures, homework, and group projects. Group projects will aim to synthesize the diverse backgrounds of the students and instructors to capture the interdisciplinary nature of the field. Students taking the course for graduate credit will complete an additional literature research project and presentation, in addition to enhanced problem sets. Offered as CSDS 386, CSDS 486, ECSE 386, ECSE 486, MATH 386, MATH 486, PHYS 386, and PHYS 486. Prereq: (CSDS 281 or ECSE 281) and (ENGR 131 or CSDS 132 or ECSE 132) and (MATH 223 or MATH 227) and (MATH 224 or MATH 228) and (PHYS 122 or PHYS 124).

ECSE 390. Advanced Game Development Project. 3 Units.

This game development project course will bring together an interprofessional group of students in the fields of engineering, computer science, and art to focus on the design and development of a complete, fully functioning computer game as an interdisciplinary team. The student teams are given complete liberty to design their own fully functional games from their original concept to a playable game published in an online marketplace. Student teams will experience the entire game development cycle as they execute their projects. Responsibilities include creating a game idea, writing a story, developing the artwork, designing characters, implementing music and sound effects, programming and testing the game, and publishing the final project. Students enrolled in 487 will develop a healthcare or education virtual environment or video game in collaboration with a mentor who has expertise in the chosen area. Offered as CSDS 390, ECSE 390, CSDS 487, and ECSE 487. Prereq: ECSE 233 and ECSE 290.

ECSE 394. Introduction to Information Theory. 3 Units.

This course is intended as an introduction to information and coding theory with emphasis on the mathematical aspects. It is suitable for advanced undergraduate and graduate students in mathematics, applied mathematics, statistics, physics, computer science and electrical engineering. Course content: Information measures-entropy, relative entropy, mutual information, and their properties. Typical sets and sequences, asymptotic equipartition property, data compression. Channel coding and capacity: channel coding theorem. Differential entropy, Gaussian channel, Shannon-Nyquist theorem. Information theory inequalities (400 level). Additional topics, which may include compressed sensing and elements of quantum information theory. Recommended preparation: MATH 201 or MATH 307. Offered as MATH 394, CSDS 394, ECSE 394, MATH 494, CSDS 494 and ECSE 494. Prereq: MATH 223 and MATH 380 or requisites not met permission.

ECSE 395. Junior Engineering Design Seminar. 3 Units.

Professional Communication course for electrical, computer, and systems and control engineering programs. Students will use engineering skills from the curriculum to pursue an engineering project. The project forms the basis for exercises for professional communication and project management. Prereq: Junior student standing or above.

ECSE 396. Independent Projects. 1 - 6 Units.

Independent projects in Computer Engineering, Electrical Engineering, and Systems and Control Engineering. Prereq: Limited to juniors and seniors.

ECSE 397. Special Topics. 1 - 6 Units.

Special topics in Computer Engineering, Electrical Engineering, and Systems and Control Engineering. Prereq: Limited to juniors and seniors.

ECSE 398. Senior Engineering Design Projects. 4 Units.

Capstone course for electrical, computer, and systems and control engineering seniors. Material from previous and concurrent courses used to solve engineering design problems. Professional engineering topics such as project management, engineering design, communications, multidisciplinary teaming, and professional ethics. Requirements include periodic reporting of progress, plus a final oral presentation and written report. Scheduled formal project presentations during last week of classes. Counts as a SAGES Senior Capstone course. Prereq or Coreq: (Senior Standing and ENGR 398 and ENGL 398) or Prereq: (Senior Standing and ECSE 395).

ECSE 399. Engineering Projects II. 3 Units.

Continuation of ECSE 398. Material from previous and concurrent courses applied to engineering design and research. Requirements include periodic reporting of progress, plus a final oral presentation and written report. Prereq: Senior Standing.

ECSE 400T. Graduate Teaching I. 0 Unit.

This course will provide the Ph.D. candidate with experience in teaching undergraduate or graduate students. The experience is expected to involve direct student contact but will be based upon the specific departmental needs and teaching obligations. This teaching experience will be conducted under the supervision of the faculty member who is responsible for the course, but the academic advisor will assess the educational plan to ensure that it provides an educational experience for the student. Students in this course may be expected to perform one or more of the following teaching related activities: grading homeworks, quizzes, and exams, having office hours for students, tutoring students. Recommended preparation: Ph.D. student in ECSE department.

ECSE 401. Digital Signal Processing. 3 Units.

Characterization of discrete-time signals and systems. Fourier analysis: the Discrete-time Fourier Transform, the Discrete-time Fourier series, the Discrete Fourier Transform and the Fast Fourier Transform. Continuoustime signal sampling and signal reconstruction. Digital filter design: infinite impulse response filters, finite impulse response filters, filter realization and quantization effects. Random signals: discrete correlation sequences and power density spectra, response of linear systems. Recommended preparation: ECSE 313.

ECSE 404. Digital Control Systems. 3 Units.

Analysis and design techniques for computer based control systems. Sampling, hybrid continuous-time/discrete-time system modeling; sampled data and state space representations, controllability, observability and stability, transformation of analog controllers, design of deadbeat and state feedback controllers; pole placement controllers based on input/output models, introduction to model identification, optimal control and adaptive control. Recommended preparation: ECSE 304 or equivalent.

ECSE 407. Engineering Economics and Financial Analysis. 3 Units.

In this course, money and profit as measures of "goodness" in engineering design are studied. Methods for economic analysis of capital investments are developed and the financial evaluation of machinery, manufacturing processes, buildings, R&D, personnel development, and other long-lived investments is emphasized. Optimization methods and decision analysis techniques are examined to identify economically attractive alternatives. Basic concepts of cost accounting are also covered. Topics include: economics criteria for comparing projects: present worth, annual worth analysis; depreciation and taxation; retirement and replacement; effect of inflation and escalation on economic evaluations; case studies; use of optimization methods to evaluate many alternatives; decision analysis; accounting fundamentals: income and balance sheets; cost accounting. Offered as ECSE 407 and EPOM 407.

ECSE 408. Introduction to Linear Systems. 3 Units.

Analysis and design of linear feedback systems using state-space techniques. Review of matrix theory, linearization, transition maps and variations of constants formula, structural properties of statespace models, controllability and observability, realization theory, pole assignment and stabilization, linear quadratic regulator problems, observers, and the separation theorem. Recommended preparation: ECSE 304.

ECSE 410. Mobile Health (mHealth) Technology. 3 Units.

Advances in communications, computer, and medical technology have facilitated the practice of personalized health, which utilizes sensory computational communication systems to support improved and more personalized healthcare and healthy lifestyle choices. The current proliferation of broadband wireless services, along with more powerful and convenient handheld devices, is helping to introduce real-time monitoring and guidance for a wide array of patients. Indeed, a large research community and a nascent industry is beginning to connect medical care with technology developers, vendors of wireless and sensing hardware systems, network service providers, and enterprise data management communities. Students in the course and labs will explore cutting-edge technologies in 1) information technologies and 2) healthcare/medical applications, through lectures, lab assignments, exams, presentations, and final projects. The overall course objectives are to introduce electrical engineering, computer engineering, and computer science students the fundamentals of wearable sensors, mobile health informatics, big data analysis, telehealthcare security & privacy, and human computer interaction considerations. Prereg: Graduate student standing.

ECSE 411. Applied Engineering Statistics. 3 Units.

In this course a combination of lectures, demonstrations, case studies, and individual and group computer problems provides an intensive introduction to fundamental concepts, applications and the practice of contemporary engineering statistics. Each topic is introduced through realistic sample problems to be solved first by using standard spreadsheet programs and then using more sophisticated software packages. Primary attention is given to teaching the fundamental concepts underlying standard analysis methods.

ECSE 413. Nonlinear Systems I. 3 Units.

This course will provide an introduction to techniques used for the analysis of nonlinear dynamic systems. Topics will include existence and uniqueness of solutions, phase plane analysis of two dimensional systems including Poincare-Bendixson, describing functions for singleinput single-output systems, averaging methods, bifurcation theory, stability, and an introduction to the study of complicated dynamics and chaos. Recommended preparation: Concurrent enrollment in ECSE 408.

ECSE 414. Wireless Communications. 3 Units.

This course introduces the fundamentals of wireless communications including backgrounds, important concepts, and cutting-edge technologies. In particular, the course focuses on interesting and important topics in wireless communications, such as (but not limited to): Overview of wireless communication networks and protocols, the cellular concept, system design fundamentals, brief introduction to wireless physical layer fundamentals, multiple access control protocols for wireless systems, wireless networking (routing/rerouting, wireless TCP/IP), mobility management, call admission control and resource allocation, revolution/evolution towards future generation wireless networks, overview of wireless mesh networks, mobile ad hoc networks and wireless sensor networks, and wireless security (optional). Offered as ECSE 316 and ECSE 414. Prereq: Graduate student or ECSE 351 with a C or better.

ECSE 415. Integrated Circuit Technology I. 3 Units.

Review of semiconductor technology. Device fabrication processing, material evaluation, oxide passivation, pattern transfer technique, diffusion, ion implantation, metallization, probing, packaging, and testing. Design and fabrication of passive and active semi-conductor devices. Recommended preparation: ECSE 322.

ECSE 416. Convex Optimization for Engineering. 3 Units.

This course will focus on the development of a working knowledge and skills to recognize, formulate, and solve convex optimization problems that are so prevalent in engineering. Applications in control systems; parameter and state estimation; signal processing; communications and networks; circuit design; data modeling and analysis; data mining including clustering and classification; and combinatorial and global optimization will be highlighted. New reliable and efficient methods, particular those based on interior-point methods and other special methods to solve convex optimization problems will be emphasized. Implementation issues will also be underscored. Recommended preparation: MATH 201 or equivalent.

ECSE 417. Computer Design - FPGAs. 3 Units.

The aim is to expose the student to methodologies for systematic design of digital systems with emphasis on programmable logic implementations and prototyping. The course requires a number of hands-on experiments and an overall lab project. The lab involves a number of class lectures to familiarize the students with the modern design techniques based on VHDL/Verilog Hardware Design Languages, CAD tools, and FPGAs. Offered as ECSE 317 and ECSE 417.

ECSE 419. Computer System Architecture. 3 Units.

Interaction between computer systems hardware and software. Pipeline techniques - instruction pipelines - arithmetic pipelines. Instruction level parallelism. Cache mechanism. I/O structures. Examples taken from existing computer systems.

ECSE 422. Solid State Electronics II. 3 Units.

Advanced physics of semiconductor devices. Review of current transport and semiconductor electronics. Surface and interface properties. P-N junction. Bipolar junction transistors, field effect transistors, solar cells and photonic devices.

ECSE 426. MOS Integrated Circuit Design. 3 Units.

Design of digital and analog MOS integrated circuits. IC fabrication and device models. Logic, memory, and clock generation. Amplifiers, comparators, references, and switched-capacitor circuits. Characterization of circuit performance with/without parasitics using hand analysis and circuit simulation. Layout of MOS and other integrated devices. Recommended preparation: ECSE 321 or similar solid-state device course. Prereq: Graduate student standing or ECSE 344.

ECSE 427. Optoelectronic and Photonic Devices. 3 Units.

In this course, we will study the optical transitions, absorptions, and gains in semiconductors. We will discuss the optical processes in semiconductor bulk as well as low dimensional structures such as quantum well and quantum dot. The fundamentals, technologies and applications of important optoelectronic devices (e.g., light-emitting diodes, semiconductor lasers, solar cells and photo-detectors) will be introduced. We will learn the current state-of-the-art of these devices. Recommended preparation: ECSE 321.

ECSE 434. Microsystems Technology. 3 Units.

This course provides an overarching coverage of microsystems technology, which is rooted in micro-electromechanical systems (MEMS). It covers the convergence of sensors and actuators, with wireless communications, computing and (social) networks. Microsystems incorporate sensors and actuators to interface computing with its physical environment-enabling perception and control. Microsystems are key enablers of smartphones, wearables, drones, robots, cars, aircrafts, weapons, etc. Recommended preparation: ECSE 322.

ECSE 438. High Performance Data and Computing. 3 Units.

High performance data and computing (HPDC) leverages parallel processing in order to maximize speed and throughput. This handson course will cover theoretical and practical aspects of HPDC. Theoretical concepts covered include computer architecture, parallel programming, and performance optimization. Practical applications will be discussed from various information and scientific fields. Practical considerations will include HPDC job management and Unix scripting. Weekly assessments and a course project will be required. Offered as CSDS 438 and ECSE 438. Prereq: ECSE 233 or graduate standing.

ECSE 450. Operations and Systems Design. 3 Units.

Introduction to design, modeling, and optimization of operations and scheduling systems with applications to computer science and engineering problems. Topics include, forecasting and times series, strategic, tactical, and operational planning, life cycle analysis, learning curves, resources allocation, materials requirement and capacity planning, sequencing, scheduling, inventory control, project management and planning. Tools for analysis include: multi-objective optimization, queuing models, simulation, and artificial intelligence.

ECSE 452. Random Signals. 3 Units.

Fundamental concepts in probability. Probability distribution and density functions. Random variables, functions of random variables, mean, variance, higher moments, Gaussian random variables, random processes, stationary random processes, and ergodicity. Correlation functions and power spectral density. Orthogonal series representation of colored noise. Representation of bandpass noise and application to communication systems. Application to signals and noise in linear systems. Introduction to estimation, sampling, and prediction. Discussion of Poisson, Gaussian, and Markov processes.

ECSE 460. Manufacturing and Automated Systems. 3 Units.

Formulation, modeling, planning, and control of manufacturing and automated systems with applications to computer science and engineering problems. Topics include, design of products and processes, location/spatial problems, transportation and assignment, product and process layout, group technology and clustering, cellular and network flow layouts, computer control systems, reliability and maintenance, and statistical quality control. Tools and analysis include: multi-objective optimization, artificial intelligence, and heuristics for combinatorial problems. Offered as ECSE 360 and ECSE 460.

ECSE 465. Computer Vision. 3 Units.

The goal of computer vision is to create visual systems that recognize objects and recover structures in complex 3D scenes. This course emphasizes both the science behind our understanding of the fundamental problems in vision and the engineering that develops mathematical models and inference algorithms to solve these problems. Specific topics include feature detection, matching, and classification; visual representations and dimensionality reduction; motion detection and optical flow; image segmentation; depth perception, multi-view geometry, and 3D reconstruction; shape and surface perception; visual scene analysis and object recognition. Offered as CSDS 465 and ECSE 465.

ECSE 466. Computer Graphics. 3 Units.

Theory and practice of computer graphics: object and environment representation including coordinate transformations image extraction including perspective, hidden surface, and shading algorithms; and interaction. Covers a wide range of graphic display devices and systems with emphasis in interactive shaded graphics. Offered as CSDS 366, ECSE 366, CSDS 466 and ECSE 466. Prereq: Graduate standing or Requisites Not Met permission.

ECSE 467. Commercialization and Intellectual Property Management. 3 Units.

This interdisciplinary course covers a variety of topics, including principles of intellectual property and intellectual property management, business strategies and modeling relevant to the creation of start-up companies and exploitation of IP rights as they relate to biomedicalrelated inventions. The goal of this course is to address issues relating to the commercialization of biomedical-related inventions by exposing law students, MBA students, and Ph.D. candidates (in genetics and proteomics) to the challenges and opportunities encountered when attempting to develop biomedical intellectual property from the point of early discovery to the clinic and market. Specifically, this course seeks to provide students with the ability to value a given technological advance or invention holistically, focusing on issues that extend beyond scientific efficacy and include patient and practitioner value propositions, legal and intellectual property protection, business modeling, potential market impacts, market competition, and ethical, social, and healthcare practitioner acceptance. During this course, law students, MBA students, and Ph.D. candidates in genomics and proteomics will work in teams of five (two laws students, two MBA students and one Ph.D. candidate), focusing on issues of commercialization and IP management of biomedical-related inventions. The instructors will be drawn from the law school, business school, and technology-transfer office. Please visit the following website for more information: fusioninnovate.com. Offered as EBME 467, ECSE 467, GENE 367, GENE 467, LAWS 5341, MGMT 467, and RGME 467.

ECSE 468. Power System Analysis I. 3 Units.

This course introduces the steady-state modeling and analysis of electric power systems. The course discusses the modeling of essential power system network components such as transformers and transmission lines. The course also discusses important steady-state analysis of three-phase power system network, such as the power flow and economic operation studies. Through the use of PowerWorld Simulator education software, further understanding and knowledge can be gained on the operational characteristics of AC power systems. Special topics concerning new grid technologies will be discussed towards the semester end. The prerequisite requirements of the course include the concepts and computational techniques of Alternative Current (AC) circuit and electromagnetic field. Offered as ECSE 368 and ECSE 468. Prereq: ECSE 245.

ECSE 469. Power System Analysis II. 3 Units.

This course extends upon the steady state analysis of power systems to cover study topics that are essential for power system planning and operation. Special system operating conditions are considered, such as unbalanced network operation and component faults. Among the most important analytical methods developed, are symmetrical components and sequence networks. Other study topics discussed include the electric machine modeling and power system transient stability. The latter half of the course presents computational methods and control algorithms that are essential for power system operation, such as generation control and state estimation. Offered as ECSE 369 and ECSE 469. Prereq: ECSE 468.

ECSE 471. Applied Circuit Design. 4 Units.

This course will consist of lectures and lab projects designed to provide students with an opportunity to consolidate their theoretical knowledge of electronics and to acquaint them with the art and practice of circuit and product design. The lectures will cover electrical and electronic circuits and many electronic and electrical devices and applications. Examples include mixed-signal circuits, power electronics, magnetic and piezo components, gas discharge devices, sensors, motors and generators, and power systems. In addition, there will be discussion of professional topics such as regulatory agencies, manufacturing, testing, reliability, and product cost. Weekly labs will be true "design" opportunities representing real-world applications. A specification or functional description will be provided, and the students will design the circuit, select all components, construct a breadboard, and test. The objective will be functional, pragmatic, cost-effective designs. Offered as ECSE 371 and ECSE 471.

ECSE 473. Modern Robot Programming. 3 Units.

The goal of this course is to learn modern methods for building up robot capabilities using the Robot Operating System (ROS). Through a sequence of assignments, students learn how to write software to control both simulated and physical robots. Material includes: interfacing software to robot I/O; path and trajectory planning for robot arms; object identification and localization from 3-D sensing; manipulation planning; and development of graphical interfaces for supervisory robot control. Laboratory assignments are scheduled in small groups to explore implementations on specific robots. Graduate students will also perform an independent project. Offered as CSDS 373, ECSE 373, CSDS 473 and ECSE 473.

ECSE 474. Advanced Control and Energy Systems. 3 Units.

This course introduces applied quantitative robust and nonlinear control engineering techniques to regulate automatically renewable energy systems in general and wind turbines in particular. The course also studies the fundamentals for dynamic multidisciplinary modeling and analysis of large multi-megawatt wind turbines (mechanics, aerodynamics, electrical systems, control concepts, etc.). The course combines lecture sessions and lab hours. The 400-level includes an experimental lab competition, where the object is to design, implement, and experimentally validate a control strategy to regulate a real system in the laboratory (helicopter control competition or similar); it will also include additional project design reports. Offered as ECSE 374 and ECSE 474. Prereq: ECSE 304.

ECSE 475. Applied Control. 3 Units.

This course provides a practical treatment of the study of control engineering systems. It emphasizes best practices in industry so that students learn what aspects of plant and control system design are critical. The course develops theory and practice for digital computer control systems; PID controller design (modes, forms and tuning methods); Control structure design (feed-forward, cascade control, predictive control, disturbance observers, multi-loop configurations, multivariable control); Actuators, sensors and common loops; Dynamic performance evaluation; and some advanced control techniques (quantitative robust control, gain-scheduling and adaptive control) to achieve a good performance over a range of operating conditions. Recommended preparation: ECSE 374 or ECSE 474. Offered as ECSE 375 and ECSE 475. Prereq: ECSE 304 or Requisites Not Met permission.

ECSE 476. Mobile Robotics. 3 Units.

Design of software systems for mobile robot control, including: motion control; sensory processing; localization and mapping; mobile-robot planning and navigation; and implementation of goal-directed behaviors. The course has a heavy lab component involving a sequence of design challenges and competitions performed in teams. Offered as CSDS 476 and ECSE 476. Prereq: ECSE 373 or ECSE 473.

ECSE 478. Computational Neuroscience. 3 Units.

Computer simulations and mathematical analysis of neurons and neural circuits, and the computational properties of nervous systems. Students are taught a range of models for neurons and neural circuits, and are asked to implement and explore the computational and dynamic properties of these models. The course introduces students to dynamical systems theory for the analysis of neurons and neural learning, models of brain systems, and their relationship to artificial and neural networks. Term project required. Students enrolled in MATH 478 will make arrangements with the instructor to attend additional lectures and complete additional assignments addressing mathematical topics related to the course. Recommended preparation: MATH 223 and MATH 224 or BIOL 300 and BIOL 306. Offered as BIOL 378, COGS 378, MATH 378, BIOL 478, CSDS 478, EBME 478, ECSE 478, MATH 478 and NEUR 478.

ECSE 480D. The Health Care Delivery Ecosystem. 3 Units.

Health care delivery across the continuum of care in the United States, including health policy and reform, financing of care, comparative health systems, population health, public health, access to care, care models, cost and value, comparative effectiveness, governance, management, accountability, workforce, and the future. Discussions of opportunities and challenges for wireless health, integrated into the foregoing topics. Perspective on health care delivery in other countries. Offered as ECSE 480D and EBME 480D.

ECSE 480F. Physicians, Hospitals and Clinics. 3 Units.

Rotation through one or more health care provider facilities for a first-hand understanding of care delivery practice, coordination, and management issues. First-hand exposure to clinical personnel, patients, medical devices and instruments, and organizational workflow. Familiarity with provider protocols, physician referral practices, electronic records, clinical decision support systems, acute and chronic care, and inpatient and ambulatory care. Offered as ECSE 480F and EBME 480F.

ECSE 480S. Wireless Health Product Development. 3 Units.

Integrating application requirements, market data, concept formulation, design innovation, and manufacturing resources for creating differentiated wireless health products that delight the user. Learning user-centric product development best practices, safety, security and privacy considerations, and risk management planning. Understanding the regulatory process. Identifying and managing product development tradeoffs. Offered as ECSE 480S and EBME 480S. Prereq: ECSE 480R.

ECSE 484. Computational Intelligence I: Basic Principles. 3 Units.

This course is concerned with learning the fundamentals of a number of computational methodologies which are used in adaptive parallel distributed information processing. Such methodologies include neural net computing, evolutionary programming, genetic algorithms, fuzzy set theory, and "artificial life." These computational paradigms complement and supplement the traditional practices of pattern recognition and artificial intelligence. Functionalities covered include self-organization, learning a model or supervised learning, optimization, and memorization.

ECSE 485. VLSI Systems. 3 Units.

Basic MOSFET models, inverters, steering logic, the silicon gate, nMOS process, design rules, basic design structures (e.g., NAND and NOR gates, PLA, ROM, RAM), design methodology and tools (spice, N.mpc, Caesar, mkpla), VLSI technology and system architecture. Requires project and student presentation, laboratory.

ECSE 486. Quantum Computing, Information, and Devices. 3 Units.

An introduction to the math, physics, engineering, and computer science underlying the rapidly emerging fields of guantum computing, guantum information, and quantum devices. The course is taught by a group of faculty from physics, engineering, computer science, and math, and is geared towards students with diverse backgrounds and interests in these fields. Students will select a concentration in one of these four areas, and the coursework, while still covering all topics, will be adjusted to focus on the selected area in the most detail. Note that the listed prerequisites depend on choice of concentration. Topics will include: 1. (Mathematics) Introduction to linear algebra, convex geometry, fundamental theory of quantum information. 2. (Physics) Introduction to the quantum mechanics of two-level systems (qubits). Survey of physics and materials for qubit technologies. 3. (Computer Science) Basic quantum gates and circuits, introduction to the theory of algorithms, survey of guantum algorithms, 4. (Engineering) Quantum architectures, mapping algorithms onto circuits. The course consists of lectures, homework, and group projects. Group projects will aim to synthesize the diverse backgrounds of the students and instructors to capture the interdisciplinary nature of the field. Students taking the course for graduate credit will complete an additional literature research project and presentation, in addition to enhanced problem sets. Offered as CSDS 386, CSDS 486, ECSE 386, ECSE 486, MATH 386, MATH 486, PHYS 386, and PHYS 486. Prereq: (CSDS 281 or ECSE 281) and (ENGR 131 or CSDS 132 or ECSE 132) and (MATH 223 or MATH 227) and (MATH 224 or MATH 228) and (PHYS 122 or PHYS 124).

ECSE 487. Advanced Game Development Project. 3 Units.

This game development project course will bring together an interprofessional group of students in the fields of engineering, computer science, and art to focus on the design and development of a complete, fully functioning computer game as an interdisciplinary team. The student teams are given complete liberty to design their own fully functional games from their original concept to a playable game published in an online marketplace. Student teams will experience the entire game development cycle as they execute their projects. Responsibilities include creating a game idea, writing a story, developing the artwork, designing characters, implementing music and sound effects, programming and testing the game, and publishing the final project. Students enrolled in 487 will develop a healthcare or education virtual environment or video game in collaboration with a mentor who has expertise in the chosen area. Offered as CSDS 390, ECSE 390, CSDS 487, and ECSE 487. Prereq: Graduate student standing.

ECSE 488. Embedded Systems Design. 3 Units.

Objective: to introduce and expose the student to methodologies for systematic design of embedded system. The topics include, but are not limited to, system specification, architecture modeling, component partitioning, estimation metrics, hardware software codesign, diagnostics.

ECSE 489. Robotics I. 3 Units.

Orientation and configuration coordinate transformations, forward and inverse kinematics and Newton-Euler and Lagrange-Euler dynamic analysis. Planning of manipulator trajectories. Force, position, and hybrid control of robot manipulators. Analytical techniques applied to select industrial robots. Recommended preparation: EMAE 181. Offered as CSDS 489, ECSE 489 and EMAE 489.

ECSE 490. Digital Image Processing. 3 Units.

Digital images are introduced as two-dimensional sampled arrays of data. The course begins with one-to-one operations such as image addition and subtraction and image descriptors such as the histogram. Basic filters such as the gradient and Laplacian in the spatial domain are used to enhance images. The 2-D Fourier transform is introduced and frequency domain operations such as high and low-pass filtering are developed. It is shown how filtering techniques can be used to remove noise and other image degradation. The different methods of representing color images are described and fundamental concepts of color image transformations and color image processing are developed. One or more advanced topics such as wavelets, image compression, and pattern recognition will be covered as time permits. Programming assignments using software such as MATLAB will illustrate the application and implementation of digital image processing. Offered as CSDS 490 and ECSE 490.

ECSE 494. Introduction to Information Theory. 3 Units.

This course is intended as an introduction to information and coding theory with emphasis on the mathematical aspects. It is suitable for advanced undergraduate and graduate students in mathematics, applied mathematics, statistics, physics, computer science and electrical engineering. Course content: Information measures-entropy, relative entropy, mutual information, and their properties. Typical sets and sequences, asymptotic equipartition property, data compression. Channel coding and capacity: channel coding theorem. Differential entropy, Gaussian channel, Shannon-Nyquist theorem. Information theory inequalities (400 level). Additional topics, which may include compressed sensing and elements of quantum information theory. Recommended preparation: MATH 201 or MATH 307. Offered as MATH 394, CSDS 394, ECSE 394, MATH 494, CSDS 494 and ECSE 494.

ECSE 499. Algorithmic Robotics. 3 Units.

This course introduces basic algorithmic techniques in robotic perception and planning. Course is divided into two parts. The first part introduces probabilistic modeling of robotic motion and sensing, Gaussian and nonparametric filters, and algorithms for mobile robot localization. The second part introduces fundamental deterministic and randomized algorithms for motion planning. Offered as CSDS 499 and ECSE 499. Prereq: Graduate Standing or Requisites Not Met permission.

ECSE 500. ECSE Colloquium. 0 Unit.

Seminars on current topics in Electrical, Computer and Systems Engineering.

ECSE 500T. Graduate Teaching II. 0 Unit.

This course will provide the Ph.D. candidate with experience in teaching undergraduate or graduate students. The experience is expected to involve direct student contact but will be based upon the specific departmental needs and teaching obligations. This teaching experience will be conducted under the supervision of the faculty member who is responsible for the course, but the academic advisor will assess the educational plan to ensure that it provides an educational experience for the student. Students in this course may be expected to perform one or more of the following teaching related activities: grading homeworks, quizzes, and exams, having office hours for students, running recitation sessions, providing laboratory assistance. Recommended preparation: Ph.D. student in ECSE department.

ECSE 526. Integrated Mixed-Signal Systems. 3 Units.

Mixed-signal (analog/digital) integrated circuit design. D-to-A and A-to-D conversion, applications in mixed-signal VLSI, low-noise and low-power techniques, and communication sub-circuits. System simulation at the transistor and behavioral levels using SPICE. Class will design a mixed-signal CMOS IC for fabrication by MOSIS. Recommended preparation: ECSE 426.

ECSE 528. RFIC Design. 3 Units.

This course covers fundamentals of the RF integrated circuit design used in radio transceivers. After brief system-level discussion and introduction of basic concepts in RF design, the course focuses on various building blocks used in radio transceiver with emphasis on main blocks used in receivers and frequency generation units such as the low noise amplifier (LNA), mixers, voltage controlled oscillators (VCO), power amplifiers (PA), and phase-locked loops (PLL). Important practical topics such as impedance matching and RF behavior of on-chip passive devices will be covered as well. Prereq: ECSE 426.

ECSE 589. Robotics II. 3 Units.

Survey of research issues in robotics. Force control, visual servoing, robot autonomy, on-line planning, high-speed control, man/machine interfaces, robot learning, sensory processing for real-time control. Primarily a project-based lab course in which students design real-time software executing on multi-processors to control an industrial robot. Recommended preparation: CSDS 489 or ECSE 489. Offered as CSDS 589 and ECSE 589.

ECSE 600. Special Topics. 1 - 18 Units.

ECSE 600T. Graduate Teaching III. 0 Unit.

This course will provide Ph.D. candidate with experience in teaching undergraduate or graduate students. The experience is expected to involve direct student contact but will be based upon the specific departmental needs and teaching obligations. This teaching experience will be conducted under the supervision of the faculty member who is responsible for the course, but the academic advisor will assess the educational plan to ensure that it provides an educational experience for the student. Students in this course may be expected to perform one or more of the following teaching related activities running recitation sessions, providing laboratory assistance, developing teaching or lecture materials presenting lectures. Recommended preparation: Ph.D. student in ECSE department.

ECSE 601. Independent Study. 1 - 18 Units.

ECSE 620. Special Topics. 1 - 18 Units.

ECSE 621. Special Projects. 1 - 18 Units.

ECSE 651. Thesis M.S.. 1 - 18 Units. Credit as arranged.

ECSE 695. Project M.S.. 1 - 9 Units.

Research course taken by Plan B M.S. students. Prereq: Enrolled in an Electrical, Computer, and Systems Engineering Plan B MS Program.

ECSE 701. Dissertation Ph.D., 1 - 9 Units.

Credit as arranged. Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.