ELECTRICAL AND COMPUTER ENGINEERING

http://www.ece.jhu.edu/

The Department of Electrical and Computer Engineering at Johns Hopkins is committed to providing a rigorous educational experience that prepares students for further study and successful careers, and is dedicated to research that contributes to fundamental knowledge in both analytical and experimental aspects of the field. The mission of our undergraduate programs is to provide a stimulating and flexible curriculum in fundamental and advanced topics in electrical and computer engineering, basic sciences, mathematics, and humanities, in an environment that fosters development of analytical, computational, and experimental skills and that involves students in design projects and research experiences. At the graduate level, our mission is to provide advanced training that prepares master's graduates to work at the forefront of their chosen specialty, and prepares doctoral students for original research that will advance the frontiers of knowledge in their chosen areas.

The department focuses its teaching and research programs in five major areas:

1. controls, networks and systems;
2. image and signal processing;
3. acoustics, speech and language processing;
4. microsystems and computer engineering, and
5. photonics and physical electronics.

The faculty offers undergraduate courses at both the introductory and intermediate levels in these areas, and graduate courses leading to research topics at the forefront of current knowledge. Guided individual study projects available for undergraduates provide opportunities for student participation in activities in the department and in the research programs of the faculty. In the graduate program, original research in close association with individual faculty members is emphasized.

Current Research Activities

Control, Networks, and Systems

Current research in control, networks, and systems includes the design and analysis of robust control algorithms; design, analysis, and performance evaluation of distributed control algorithms for networked dynamical systems; real-time optimization of dynamical systems; multi-time scale optimization decomposition of networked systems. Application domains include systems and synthetic biology, particularly the analysis of signaling pathways in biological systems; power systems, including multi-timescale market design and co-optimization, distributed control design for frequency regulation, real-time congestion management, and low inertia power systems control; information networks, including the design of clock synchronization algorithms, and joint congestion control and multi-path routing for data networks.

Image and Signal Processing

Image analysis efforts currently concern statistical analysis of restoration, learning, and reconstruction algorithms, development of statistical image models for image restoration and segmentation, geometric modeling for object detection and estimation, morphological image analysis, magnetic resonance imaging, ultrasound imaging, and photoacoustic imaging. There is opportunity for joint work in image analysis and signal processing with faculty in the Department of Radiology and various other departments within the School of Medicine.

Acoustics, Speech and Language Processing

Research in speech processing involves work in all aspects of language or speech science and technology, with fundamental studies under way in areas such as language modeling, pronunciation modeling, natural language processing, neural auditory processing, acoustic processing, optimality theory, and language acquisition. Research starting at the materials used for transduction of acoustic signals, through signal processing involved in extract relevant information from the acoustic signatures, and leading to the interpretation of the information to extract meaning and/or translating between languages.

Microsystems and Computer Engineering

Computer engineering research activities include work on computer structures (with emphasis on microprocessors), parallel and distributed processing, fault-tolerant computing, analysis of algorithms, VLSI analog architectures for machine intelligence and sensory processing, associative processing, and micropower computing, alternative computation systems and devices, applied neuroscience, hardware-friendly algorithms and MEMS.

Photonics and Physical Electronics

Current research activities include work in fiber optic sensors and endoscopic 3-D imaging devices for medical applications, secure optical communications, and semiconductor optoelectronics. Other areas of interest involve the study of the nonlinear interactions of light with matter, laser beam control and steering, and plasmonics. Semiconductor device studies include optical detectors, photovoltaics, silicon photonics, nanophotonics, quantum cascade lasers, high power III-Nitride electronic devices, VLSI circuit design and modeling and microwave devices and circuits. Study of a laser radar and RF photonics is also being pursued. Theoretical and experimental studies involving linear optical properties of various materials and passive remote sensing of the atmosphere are being investigated.

Facilities

The department maintains extensive facilities for teaching and research in Barton Hall, Hackerman Hall, Wyman, and Maryland Hall. The two main teaching labs (Microprocessor & FPGA Lab and the Biophotonics Lab) make extensive use of state-of-the-art design environments such as CADENCE, Xilinx Tools, TI DSP systems, VHDL, and Verilog. In addition, the department includes the computational sensory motor system lab, the cellular signaling control lab, the parallel computing and imaging lab, the photonics and optoelectronics lab, the semiconductor microstructures lab, and the sensory communication and microsystem lab, adaptive and the sensory communication microsystem lab.

Undergraduate Programs

The Department of Electrical and Computer Engineering offers three bachelor's degree programs: a BS in Electrical Engineering, a BS in Computer Engineering (with the close collaboration of the Computer Science Department (http://e-catalog.jhu.edu/engineering/computer-science/)), and a BA in Electrical & Computer Engineering. Students learn the fundamentals of electrical, computer and digital systems, data structures, and circuits, with an emphasis on hands-on experience to complement the theoretical. Please note that the BA degree is not accredited through ABET. However, both BS degree programs are accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org (http://www.abet.org/).

Graduate Programs

Graduate students work closely with their faculty advisors to design a plan based on their needs and interests. Our faculty understand industry demands a broad skill set coupled with research and design experience, and our curriculum offers the opportunity to meld theory and practice. Students are required to take at least five classes in ECE and an additional three courses in other engineering disciplines. Students have three options for completing their degree requirements: taking two additional courses; completing a master's essay/thesis; or completing a project. Additional details can be found in the department's *Graduate Student Advising Manual*.

Combined Undergraduate/ Graduate Program

At the end of their sophomore year, students who are majors in electrical and computer engineering may apply for admission to the combined bachelor's/master's program which combines a B.S. in electrical engineering with a master of science in engineering. In order to qualify, students must maintain GPA of 3.5 or higher. The latest deadline to apply for this program is the end of their second to last semester. The application process is explained at http://engineering.jhu.edu/ece/undergraduatestudies/concurrent-bachelorsmasters/. (http://engineering.jhu.edu/ece/undergraduatestudies/concurrent-bachelorsmasters/)

Programs

- Computer Engineering, Bachelor of Science (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/computer-engineering-bachelor-science/)
- Computer-Integrated Surgery, Minor (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/computer-integrated-surgery-minor/)
- Electrical and Computer Engineering, Master of Science in Engineering (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/electrical-computer-master-science-engineering/)
- Electrical and Computer Engineering, PhD (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/electrical-computer-engineering-phd/)
- Electrical Engineering, Bachelor of Arts (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/electrical-engineering-bachelor-arts/)
- Electrical Engineering, Bachelor of Science (http://e-catalog.jhu.edu/engineering/full-time-residential-programs/degree-programs/electrical-computer-engineering/electrical-engineering-bachelor-science/)

For current course information and registration go to https://sis.jhu.edu/classes/

Courses

EN.520.123. Computational Modeling for Electrical and Computer Engineering. 3 Credits.
In this course, the students will acquire the skills of solving complex real world Electrical and Computer Engineering problems using computational modeling tools. This course will covert two aspects ofsolving those ECE problems. The first aspect consists of learning to map ECE tasks to mathematical models. The second aspect consists of introducing the students to the basic of computational algorithms needed to work with the models, and programming such algorithms in MATLAB.
Area: Engineering

EN.520.137. Introduction To Electrical & Computer Engineering. 3 Credits.
An introductory course covering the principles of electrical engineering including sinusoidal wave forms, electrical measurements, digital circuits, and applications of electrical and computer engineering. Laboratory exercises, the use of computers, and a design project are included in the course.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.142. Digital Systems Fundamentals. 3 Credits.
Number systems and computer codes, switching functions, minimization of switching functions, Quine - McCluskey method, sequential logic, state tables, memory devices, analysis, and synthesis of synchronous sequential devices.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.150. Light, Image and Vision. 3 Credits.
This course is designed for beginning undergraduate students and covers the principle of optics and imaging from the human vision perspective. The topics for the course include the basic principles and properties of light, imaging and image formation, optical imaging and display systems, and human vision. The course include bio-weekly labs that allows students to implement and experience the concepts learned during the lectures.
Area: Engineering

EN.520.211. ECE Engineering Team Project. 1 Credit.
This course introduces the student to the basics of engineering team projects. The student will become a member of and participate in the different aspects of an ECE team project over several semesters. (Freshmen and Sophomores)
Area: Engineering

EN.520.212. ECE Engineering Team Project (Freshmen and Sophomores). 1 Credit.
This course introduces the student to the basics of engineering team projects. The student will participate in an ECE engineering team project as a member. The student is expected to participate in the different aspects of the project over several semesters. (Freshmen and Sophomores)Permission of instructor required.
Area: Engineering

EN.520.214. Signals and Systems. 4 Credits.
An introduction to discrete-time and continuous-time signals and systems covers representation of signals and linear time-invariant systems and Fourier analysis.
Prerequisite(s): (AS.110.107 OR AS.110.109);AS.110.202 can be taken while taking EN.520.214
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.216. Introduction To VLSI. 3 Credits.
This course teaches the basics of switch-level digital CMOS VLSI design. This includes creating digital gates using MOS transistors as switches, laying out a design using CAD tools, and checking the design for conformance to the Scalable CMOS design rules.Recommended: EN.520.213.
Prerequisite(s): (AS.171.101 AND AS.171.102) OR (AS.171.101 AND AS.171.108) OR (AS.171.102 AND AS.171.107) OR (AS.171.107 AND AS.171.108)
Area: Engineering

EN.520.219. Introduction to Electromagnetics. 3 Credits.
Vector analysis, electrostatic fields in vacuum and material media, stationary currents in conducting media, magnetostatic fields in vacuum and material media. Maxwell's equations and time-dependent electric and magnetic fields, electromagnetic waves and radiation, transmission lines, wave guides, applications.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering, Natural Sciences

EN.520.220. Electromagnetic Waves. 3 Credits.
Magnetostatic fields in vacuum and material media. Maxwell's equations and time-dependent electric and magnetic fields, electromagnetic waves and radiation, transmission lines, wave guides, applications.
Area: Engineering, Natural Sciences

EN.520.222. Computer Architecture. 3 Credits.
A study of the structure and organization of classical von Neuman uniprocessor computers. Topics include a brief history of modern machines starting from the Turing computer model, instruction sets, addressing, RISC versus CICS, traps and interrupt handling, twos complement arithmetic, adders and ALUs, CSA's Booth's algorithm, multiplication and division, control unit design, microprogramming, dynamic versus static linking, memory systems and memory hierarchy, paging segmentation, cache hardware, cache organizations, and replacement policies.
Area: Engineering

EN.520.225. Advanced Digital Systems. 3 Credits.
Students are introduced to Hardware Description Languages (HDL) through the assembly of virtual versions of the digital parts used in the previous semester's Digital Systems Fundamentals. From this point on, new components called modules are created as needed to implement larger digital circuits. Increasingly complex digital systems are then created through stages such as desktop calculators, and culminating in the design of microcontrollers and microprocessors.The hardware used for the digital systems designed is a custom board containing a Field Programmable Gate Array (FPGA). This board is configured using software on the student's computer, but is designed to standalone. That is, once configured, it no longer needs to be connected to any host computer.The architecture of these complex digital systems starts with Finite State Machines (FSM). Hierarchical FSMs are then covered, followed by traditional two and three bus microprocessor architectures and digital signal processors.
Prerequisite(s): EN.520.142
Area: Engineering

EN.520.230. Mastering Electronics. 2 Credits.
With this course, students will have a solid understanding of basic and fundamental electronic concepts and rules including resistive circuits, loop and node analysis, capacitor/inductor circuits, and transient analysis. Students will be able to build, design, and simulate a wide range of electronic devices; the class will focus on building and designing audio devices. Class lectures cover the fundamental concepts of electronics, followed by laboratory exercises that demonstrate the basic concepts. Students will learn to simulate circuits using SPICE. A final project is required. Prereqs: Physical Science Majors II (AS.171.102); General Physics Laboratory (AS.173.112).
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.; (AS.110.108 AND AS.110.109) AND ((171.101 AND 171.102) OR (171.101 AND 171.108) OR (171.102 AND 171.107) OR (171.107 AND 171.108) AND AS.173.112)
Corequisite(s): EN.520.231
Area: Engineering

EN.520.231. Mastering Electronics Laboratory. 2 Credits.
With this course, students will have a solid understanding of basic and fundamental electronic concepts and rules including resistive circuits, loop and node analysis, capacitor/inductor circuits, and transient analysis. Students will be able to build, design, and simulate a wide range of electronic devices; the class will focus on building and designing audio devices. Class lectures cover the fundamental concepts of electronics, followed by laboratory exercises that demonstrate the basic concepts. Students will learn to simulate circuits using SPICE. A final project is required.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.; (AS.110.108 AND AS.110.109) AND ((171.101 AND 171.102) OR (171.101 AND 171.108) OR (171.102 AND 171.107) OR (171.107 AND 171.108)) AND AS.173.112)
Corequisite(s): EN.520.230 Mastering Electronics
Area: Engineering

EN.520.250. Leading Innovation Design Team. 1 Credit.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.edu. Students must take the class as a graded course. S/U is not an option.For additional info, see link below: https://engineering.jhu.edu/ece/undergraduate-studies/leading-innovation-design-team/
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class.
Area: Engineering

EN.520.251. Leading Innovation Design Team. 1 Credit.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first-hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.edu
Prerequisite(s): Students may receive credit for only one of the following courses; EN.520.251, EN.520.463 OR EN.520.663.;Laboratory Safety Introductory Course available in MyLearning prior to registration. The course is accessible from the Education tab through the portal my.jh.edu. Please note that this requirement is not applicable to new students registering for their first semester at Hopkins.
Area: Engineering

EN.520.302. Internet of Things Project Lab. 3 Credits.
In this course the student configures, programs, and tests microprocessor modules with wireless interconnectivity for embedded monitoring and control purposes. Several different platforms are explored and programmed in high level languages (HLL). Upon completion, students can use these devices as elements in other project courses.Recommended Course Background: HLL programming and digital logic familiarity; Advanced Microprocessor Lab is a plus.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering

EN.520.315. Intro. to Bio-Inspired Processing of Audio-Visual Signals. 3 Credits.
An introductory course to basic concepts of information processing of human communication signals (sounds, images) in living organisms and by machine. Recommended Course Background: EN.520.214 (or EN.580.222) or consent of the instructor.
Area: Engineering

EN.520.340. Introduction to Mechatronics. 3 Credits.
Introduction to Mechatronics is mostly hands-on, interdisciplinary design class consisting of lectures about key topics in mechatronics, and lab activities aimed at building basic professional competence. After completing the labs, the course will be focused on a final mini-project for the remainder of the semester. This course will encourage and emphasize active collaboration with classmates. Each team will plan. design, manufacture and/or build, test, and demonstrate a robotic system that meets the specified objectives.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering

EN.520.344. Introduction to Digital Signal Processing. 3 Credits.
Introduction to digital signal processing, sampling and quantization, discrete time signals and systems, convolution, Z-transforms, transfer functions, fast Fourier transform, analog and digital filter design, A/D and D/A converters, and applications of DSP.
Prerequisite(s): EN.520.214
Area: Engineering

EN.520.349. Microprocessor Lab I. 3 Credits.
This course introduces the student to the programming of microprocessors at the machine level. 68HC08, 8051, and eZ8 microcontrollers are programmed in assembly language for embedded control purposes. The architecture, instruction set, and simple input/output operations are covered for each family. Upon completion, students can use these flash-based chips as elements in other project courses. Recommended Course Background: EN.520.142 or equivalent.The lab is open 24/7 and students can still take the class if they are unable to meet during lab time.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering

EN.520.353. Control Systems. 3 Credits.
Modeling, analysis, and an introduction to design for feedback control systems. Topics include state equation and transfer function representations, stability, performance measures, root locus methods, and frequency response methods (Nyquist, Bode).
Prerequisite(s): EN.520.214 OR EN.530.343 OR EN.580.222
Area: Engineering

EN.520.370. Introduction to Renewable Energy Engineering. 3 Credits.
This course provides an introduction to the science and engineering of renewable energy technologies. The class will begin with an overview of today's energy landscape and proceed with an introduction to thermodynamics and basic heat engines. Specific technologies to be discussed include photovoltaics, fuel cells and hydrogen, biomass, wind power and energy storage. The class should be accessible to those from a variety of science and engineering disciplines. Recommended Course Background: Introductory Physics and Calculus.
Prerequisite(s): (AS.171.101 OR AS.171.105 OR AS.171.107 OR EN.530.123) AND AS.110.109
Area: Engineering, Natural Sciences

EN.520.372. Programmable Device Lab. 3 Credits.
The use of programmable memories (ROMs, EPROMs, and EEPROMs) as circuit elements (as opposed to storage of computer instructions) is covered, along with programmable logic devices (PALs and GALs). These parts permit condensing dozens of standard logic packages (TTL logic) into one or more off-the-shelf components. Students design and build circuits using these devices with the assistance of CAD software. Topics include programming EEPROMs; using PLDs as address decoders; synchronous sequential logic synthesis for PLDs; and PLD-based state machines.Recommended Course Background: EN.520.142 and EN.520.345
Area: Engineering

EN.520.385. Signals, Systems, & Learning. 3 Credits.
This course builds on the fundamentals of signal processing to explore state space models and random processes. Topics include LTI systems, feedback, probabilistic models, signal estimation, random processes, power spectral density and hypothesis testing.
Prerequisite(s): (EN.580.222 OR EN.520.214) AND EN.550.310 AND AS.110.201
Area: Engineering

EN.520.403. Introduction to Optical Instruments. 3 Credits.
This course is intended to serve as an introduction to optics and optical instruments that are used in engineering, physical, and life sciences. The course covers first basics of ray optics with the laws of refraction and reflection and goes on to description of lenses, microscopes, telescopes, and imaging devices. Following that basics of wave optics are covered, including Maxwell equations, diffraction and interference. Operational principles and performance of various spectrometric and interferometric devices are covered including both basics (monochromatic, Fabry-Perot and Michelson interferometers), and advanced techniques of near field imaging, laser spectroscopy, Fourier domain spectroscopy, laser Radars and others.
Area: Engineering

EN.520.404. Engineering solutions in a global, economic, environmental, and societal context. 1 Credit.
Students will examine ECE based case studies and will apply decision making theory and leadership theory as it relates to information, communication, healthcare, and energy. The course aims to examine technology as it transitions from old to new, from impossible to possible. It will also evaluate the new hazards that these new technologies may have on the world. The students will have to quantify the good and the bad of each solution and weigh their contribution to Environment, Economy, society and Healthcare. The group will present these case studies to their classmates, justifying the solutions and answers to the ethical dilemmas they faced, and explain the impact of their decisions from an economic, environmental, and global perspective.
Corequisite(s): EN.660.400
Area: Humanities

EN.520.412. Machine Learning for Signal Processing. 3 Credits.
This course will focus on the use of machine learning theory and algorithms to model, classify and retrieve information from different kinds of real world complex signals such as audio, speech, image and video.
Prerequisite(s): Students can only take EN.520.412 OR EN.520.612, not both.;AS.110.201 AND EN.553.310 AND (EN.520.435 OR EN.520.344)
Area: Engineering

EN.520.414. Image Processing & Analysis. 3 Credits.
The course covers fundamental methods for the processing and analysis of images and describes standard and modern techniques for the understanding of images by humans and computers. Topics include elements of visual perception, sampling and quantization, image transforms, image enhancement, color image processing, image restoration, image segmentation, and multiresolution image representation. Laboratory exercises demonstrate key aspects of the course.
Prerequisite(s): EN.520.214 OR EN.580.222 OR (EN.580.243 AND EN.580.246)
Area: Engineering

EN.520.415. Image Process & Analysis II. 3 Credits.
This course covers fundamental methods for the processing and analysis of images and describes standard and modern techniques for the understanding of images by morphological image processing and analysis, image representation and description, image recognition and interpretation.
Area: Engineering

EN.520.417. Computation for Engineers. 3 Credits.
Designing algorithms in a finite precision environment that are accurate, fast, and memory efficient is a challenge that many engineers must face. This course will provide students with the tools they need to meet this challenge. Topics include floating point arithmetic, rounding and discretization errors, problem conditioning, algorithm stability, solving systems of linear equations and least-squares problems, exploiting matrix structure, interpolation, finding zeros and minima of functions, computing Fourier transforms, derivatives, and integrals. Matlab is the computing platform.Background in linear algebra, matrices, digital signal processing, Matlab.
Area: Engineering

EN.520.424. FPGA Synthesis Lab. 3 Credits.
An advanced laboratory course in the application of FPGA technology to information processing, using VHDL synthesis methods for hardware development. The student will use commercial CAD software for VHDL simulation and synthesis, and implement their systems in programmable XILINX 20,000 gate FPGA devices. The lab will consist of a series of digital projects demonstrating VHDL design and synthesis methodology, building up to final projects at least the size of an 8-bit RISC computer. Projects will encompass such things as system clocking, flip-flop registers, state-machine control, and arithmetic. The students will learn VHDL methods as they proceed through the lab projects, and prior experience with VHDL is not a prerequisite.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.427. Design of Biomedical Instruments and Systems. 3 Credits.
The purpose of this course is to teach the students principles of product design for the biomedical market. From an idea to a product and all the stages in-between.The course material will include identification of the need, market survey, patents. Funding sources and opportunities, Regulatory requirements, Reimbursement codes, Business models). Integration of the system into the clinical field. system connectivity. Medical information systems. Medical standards (DICOM, HL-7, ICD, Medical information bus). How to avoid mistakes in system design and in system marketing. Entrepreneurship.The course participants will be divided to groups of 2-3 students each. Each group will be acting as a start-up company throughout the whole semester. Each group will need to identify a need. This can be done by meeting and interviewing medical personnel, at the Johns Hopkins Medical campus or other hospitals, clinics, HMOs, assisted living communities or other related to the medical world. The proposed medical instrument or system can be a combination of instrument and software.Each week, there will be a lecture devoted to the principal subjects mentioned above. Afterwards the students will present their ideas and progress to all class participants. There will be an open discussion for each of the projects. The feedback from class will help the development of the product. Each presentation, document, survey or paper will be kept in the course cloud which will have a folder for each of the groups. The material gathered in this folder will be built gradually throughout the semester. Eventually it will become the product blueprint.At the last week of the semester, the groups will present their product to a panel of experts involved with the biotech industry, in order to “convince” them to invest in their project.Previous years’ projects are listed in this website: (https://jhuecepdl.bitbucket.io).
Area: Engineering

EN.520.432. Medical Imaging Systems. 3 Credits.
This course provides students with an introduction to the physics, instrumentation, and signal processing methods used in general radiography, X-ray computed tomography, ultrasound imaging, magnetic resonance imaging, and nuclear medicine. The primary focus is on the methods required to reconstruct images within each modality from a signals and systems perspective, with emphasis on the resolution, contrast, and signal-to-noise ratio of the resulting images. Students will additionally engage in hands-on activities to reconstruct medical images from raw data.
Prerequisite(s): EN.520.214 OR EN.580.222 OR (EN.580.243 AND EN.580.246)
Area: Engineering

EN.520.433. Medical Image Analysis. 3 Credits.
This course covers the principles and algorithms used in the processing and analysis of medical images. Topics include, interpolation, registration, enhancement, feature extraction, classification, segmentation, quantification, shape analysis, motion estimation, and visualization. Analysis of both anatomical and functional images will be studied and images from the most common medical imaging modalities will be used. Projects and assignments will provide students experience working with actual medical imaging data.
Prerequisite(s): EN.550.310 OR EN.550.311 OR EN.560.348
Area: Engineering

EN.520.434. Modern Biomedical Imaging Instrumentation and Techniques. 3 Credits.
An intermediate biomedical imaging course covering modern biomedical imaging instrumentation and techniques as applied to diagnostic radiology and other biomedical applications. It includes recent advances in various biomedical imaging modalities, multi- modality imaging and molecular imaging. The course is team taught by experts in the respective fields and provides a broad based knowledge of modern biomedical imaging to prepare students for graduate studies and research in biomedical imaging. Also, the course will offer tours and practical experience with modern biomedical imaging equipments in clinical and research settings. Co-listed with EN.580.473
Prerequisite(s): Students may not have taken EN.520.634

EN.520.435. Digital Signal Processing. 3 Credits.
Methods for processing discrete-time signals. Topics include signal and system representations, z- transforms, sampling, discrete Fourier transforms, fast Fourier transforms, digital filters.
Area: Engineering

EN.520.438. Deep Learning. 3 Credits.
Deep Learning is emerging as one of the most successful tools in machine learning for feature learning and classification. This course will introduce students to the basics of Neural Networks and expose them to some cutting-edge research. In particular, this course will provide a survey of various deep learning-based architectures such as autoencoders, recurrent neural networks and convolutional neural networks. We will discuss merits and drawbacks of available approaches and identify promising avenues of research in this rapidly evolving field. Various applications related to computer vision and biometrics will be studied. The course will include a project, which will allow students to explore an area of Deep Learning that interests them in more depth.
Prerequisite(s): EN.520.435 AND EN.601.220 AND EN.553.420
Area: Engineering

EN.520.445. Audio Signal Processing. 3 Credits.
This course gives a foundation in current audio and speech technologies, and covers techniques for sound processing by processing and pattern recognition, acoustics, auditory perception, speech production and synthesis, speech estimation. The course will explore applications of speech and audio processing in human computer interfaces such as speech recognition, speaker identification, coding schemes (e.g. MP3), music analysis, noise reduction. Students should have knowledge of Fourier analysis and signal processing.
Area: Engineering

EN.520.447. Information Theory. 3 Credits.
This course will address some basic scientific questions about systems that store or communicate information. Mathematical models will be developed for (1) the process of error-free data compression leading to the notion of entropy, (2) data (e.g. image) compression with slightly degraded reproduction leading to rate-distortion theory and (3) error-free communication of information over noisy channels leading to the notion of channel capacity. It will be shown how these quantitative measures of information have fundamental connections with statistical physics (thermodynamics), computer science (string complexity), economics (optimal portfolios), probability theory (large deviations), and statistics (Fisher information, hypothesis testing).
Prerequisite(s): EN.553.310 OR EN.553.420 OR EN.553.311;Students can earn credit for either EN.520.447 or EN.520.647, but not both.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.448. Electronics Design Lab. 3 Credits.
An advanced laboratory course in which teams of students design, build, test and document application specific information processing microsystems. Semester long projects range from sensors/actuators, mixed signal electronics, embedded microcomputers, algorithms and robotics systems design. Demonstration and documentation of projects are important aspects of the evaluation process.Recommended: EN.600.333, EN.600.334, EN.520.214, EN.520.216, EN.520.349, EN.520.372, EN.520.490 or EN.520.491.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.; (EN.520.240 OR EN.520.340 OR EN.520.230 OR EN.520.213) AND AS.110.108 AND AS.110.109 AND ((171.101 AND 171.102) OR (171.101 AND 171.108) OR (171.102 AND 171.107) OR (171.107 AND 171.108)) AND EN.520.142.

EN.520.450. Advanced Micro-Processor Lab. 3 Credits.
This course covers the usage of common microcontroller peripherals. Interrupt handling, timer operations, serial communication, digital to analog and analog to digital conversions, and flash ROM programming are done on the 68HC08, 8051, and eZ8 microcontrollers. Upon completion, students can use these flash-based chips as elements in other project courses. Recommended Course Background: EN.520.349
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.452. Advanced ECE Engineering Team Project. 3 Credits.
This course introduces the student to running an ECE engineering team project. The student will participate in the team project as a leading member and is expected to manage both the team members and the different aspects of the project over several semesters. Permission of the instructor is required for new team members. (Junior and Seniors)
Area: Engineering

EN.520.453. Advanced ECE Engineering Team Project. 3 Credits.
The course introduces the student to running an engineering team project. The student will participate in the ECE engineering team project as a leading member. The student is expected to participate in the different aspects of the project over several semesters and manage both team members and the project.(Juniors and Seniors) Permission of instructor is required.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering

EN.520.454. Control Systems Design. 3 Credits.
Classical and modern control systems design methods. Topics include formulation of design specifications, classical design of compensators, state variable and observer based feedback. Computers are used extensively for design, and laboratory experiments are included.
Area: Engineering

EN.520.457. Basics of Wave and Quantum Mechanics. 3 Credits.
Basic principles of quantum mechanics for engineers. Topics include the quantum theory of simple systems, in particular atoms and engineered quantum wells, the interaction of radiation and atomic systems, and examples of application of the quantum theory to lasers and solid-state devices. Recommended Course Background: AS.171.101-AS.171.102 and EN.520.219-EN.520.220
Area: Engineering

EN.520.460. The Art of Error Control Coding. 3 Credits.
Error control coding is the study and practice of detecting and/or correcting errors that occur in the transmission of digital information over a noisy communication channel, the transferal of information to and from memory and mass storage in a computer, or in any other application where random processes corrupt information. The student will study encoders and decoders for the most important codes in current use and will confront realistic problems in the use of coding. The course will comprise lectures, discussions, and projects.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.462. Leading Innovation Design Team. 3 Credits.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.eduFor additional info, see: https://engineering.jhu.edu/ece/undergraduate-studies/leading-innovation-design-team/
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class.
Area: Engineering

EN.520.463. Leading Innovation Design Team. 3 Credits.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first-hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.edu
Prerequisite(s): Students may receive credit for only one of the following courses; EN.520.251, EN.520.463 OR EN.520.663.;Laboratory Safety Introductory Course available in MyLearning prior to registration. The course is accessible from the Education tab through the portal my.jh.edu. Please note that this requirement is not applicable to new students registering for their first semester at Hopkins.
Area: Engineering

EN.520.470. Infra-Red Sensing & Technologies. 3 Credits.
Infrared technologies have evolved over the last sixty, primarily driven by defense applications and needs but have recently perforated into various non-defense markets. It remains critical to many military systems and increasing to autonomous systems in general. This course is intended as an overview of the various technologies that make up an infrared sensor system, it will include some historical perspectives as well as the state of the art and will emphasize the various tradeoffs involved in designing a system for particular applications. In particular, it will cover the following topics that represent the main components: optics, detectors, readout integrated circuits (ROIC) including digital designs, the various wavelength (SWIR, MWIR, LWIR), testing and calibration, image and signal processing, and applications. The course structure will involve lectures, labs, and final project. Lectures will involve guest speakers that are subject matter experts on the various topics.
Area: Engineering

EN.520.471. Speech Technologies Reading Group. 1 Credit.
Reading group that explores novel algorithms and papers on speech technologies

EN.520.473. Magnetic Resonance in Medicine. 3 Credits.
This course provides a wide-ranging introduction to the physics and principles of magnetic resonance imaging (MRI). Topics include the resonance phenomenon, relaxation, signal formation, spatial localization, image contrast, hardware, signal processing, and image reconstruction. MATLAB simulation exercises will demonstrate key aspects of MRI and a laboratory component using the clinical MRI systems at the School of Medicine will reinforce concepts learned in class. Textbook "Principles of Magnetic Resonance Imaging" by D. Nishimura (from www.lulu.com) should be obtained before the start of the course. Recommended Course Background: (EN.520.434 or EN.580.473) or (EN.520.432 or EN.580.472). Co-listed with EN.580.476 and EN.580.673.
Area: Engineering, Natural Sciences

EN.520.482. Introduction To Lasers. 3 Credits.
This course covers the basic principles of laser oscillation. Specific topics include propagation of rays and Gaussian beams in lens-like media, optical resonators, spontaneous and stimulated emission, interaction of optical radiation and atomic systems, conditions for laser oscillation, homogeneous and inhomogeneous broadening, gas lasers, solid state lasers, Q-switching and mode locking of lasers.
Prerequisite(s): AS.171.102 OR AS.171.108
Area: Engineering, Natural Sciences

EN.520.483. Bio-Photonics Laboratory. 3 Credits.
This laboratory course involves designing a set of basic optical experiments to characterize and understand the optical properties of biological materials. The course is designed to introduce students to the basic optical techniques used in medicine, biology, chemistry and material sciences.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.485. Advanced Semiconductor Devices. 3 Credits.
This course is designed to develop and enhance the understanding of the operating principles and performance characteristics of the modern semiconductor devices used in high speed optical communications, optical storage and information display. The emphasis is on device physics andfabrication technology. The devices include heterojunction bipolar transistors, high mobility FET's, semiconductor lasers, laser amplifiers, light-emitting diodes, detectors, solar cells and others.
Area: Engineering, Natural Sciences

EN.520.486. Physics of Semiconductor Electronic Devices. 3 Credits.
The course is designed to develop and enhance the understanding of the physical principles of modern semiconductor electronic and opto-electronic devices. The course starts with the basics of band structure of solid with emphasis on group IV and III-V semiconductors as well as two dimensional semiconductors like graphene. It continues with the statistics of carriers in semiconductors and continues to electronic transport properties, followed by optical properties. The course goes on to investigate the properties of two dimensional electronic gas. The second part of the course describes operational principles of bipolar and unipolar transistors, light emitting diodes, photodetectors, and quantum devices.
Prerequisite(s): Students may earn credit for EN.520.486 or EN.520.686, but not both.;AS.171.102 OR AS.171.108

EN.520.491. CAD Design of Digital VLSI Systems I (Juniors/Seniors). 3 Credits.
Juniors and Seniors Only.
Prerequisite(s): Student may take EN.520.491 or EN.520.691, but not both.;AS.110.109 AND (AS.171.102 OR AS.171.104 OR AS.171.108) AND EN.520.142 AND EN.520.142 AND (EN.520.230 OR (EN.520.213 AND EN.520.345 OR EN.520.216))
Area: Engineering

EN.520.492. Mixed-Mode VLSI Systems. 3 Credits.
Silicon models of information and signal processing functions, with implementation in mixed analog and digital CMOS integrated circuits. Aspects of structured design, scalability, parallelism, low power consumption, and robustness to process variations. Topics include digital-to-analog and analog-to-digital conversion, delta-sigma modulation, bioinstrumentation, and adaptive neural computation. The course includes a VLSI design project. Recommended Course Background: EN.521.491 or equivalent.
Area: Engineering

EN.520.495. Microfabrication Laboratory. 4 Credits.
This laboratory course is an introduction to the principles of microfabrication for microelectronics, sensors, MEMS, and other synthetic microsystems that have applications in medicine and biology. Course comprises of laboratory work and accompanying lectures that cover silicon oxidation, aluminum evaporation, photoresist deposition, photolithography, plating, etching, packaging, design and analysis CAD tools, and foundry services. Seniors only or Perm. Req'd. Co-listed as EN.580.495 & EN.530.495
Prerequisite(s): AS.171.102 OR AS.171.108
Area: Engineering, Natural Sciences

EN.520.498. Senior Design Project. 3 Credits.
Capstone design project, in which a team of students engineers a system and evaluates its performance in meeting design criteria and specifications. Example application areas are micro-electronic information processing, image processing, speech recognition, control, communications, and biomedical instrumentation. The design needs to demonstrate creative thinking and experimental skills, and needs to draw upon knowledge in basic sciences, mathematics, and engineering sciences. Interdisciplinary participation, such as by biomedical engineering, mechanical engineering, and computer science majors, is strongly encouraged. Instructor permission required.
Area: Engineering

EN.520.499. Senior Design Project. 3 Credits.
Capstone design project, in which a team of students engineer a system and evaluate its performance in meeting design criteria and specifications. Example application areas are microelectronic information processing, image processing, speech recognition, control, communications and biomedical instrumentation. The design needs to demonstrate creative thinking and experimental skills, and needs to draw upon knowledge in basic sciences, mathematics and engineering sciences. Interdisciplinary participation, such as by biomedical engineering, mechanical engineering and computer science majors, is strongly encouraged.
Area: Engineering

EN.520.502. Indep Study - Fresh/Soph. 0 - 3 Credits.
Individual, guided study under the direction of a faculty member in the department. The program of study or research, including the credit to be assigned, must be worked out in advance between the student and the faculty member involved.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Area: Engineering

EN.520.503. Independent Study-Juniors-Seniors. 3 Credits.
Individual, guided study under the direction of a faculty member in the department. The program of study or research, including the credit to be assigned, must be worked out in advance between the student and the faculty member involved. May be taken either term by juniors or seniors. Instructor permission required.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.504. Independent Study - Juniors/Seniors. 0 - 3 Credits.
Individual study, including participation in research, under the guidance of a faculty member in the department. The program of study or research, time required, and credit assigned must be worked out in advance between the student and the faculty member involved. May be taken either term by juniors or seniors.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.506. ECE Undergraduate Research. 1 - 3 Credits.
Independent research under the direction of a faculty member in the department. The program of research, including the credit to be assigned, must be worked out in advance between the student and the faculty member involved.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.516. ECE Group Undergraduate Research. 1 - 3 Credits.
Independent research under the direction of a faculty member in the department. The program of research, including the credit to be assigned, must be worked out in advance between the student and the faculty member involved. This section has a weekly research group meeting that students are expected to attend.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.550. Electrical Engineering - Internship. 0 - 3 Credits.

EN.520.595. Independent Study. 3 Credits.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.597. Research - Summer. 3 Credits.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.599. Internship - Summer. 1 Credit.
Prerequisite(s): You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.

EN.520.600. Electrical & Computer Engineering Seminar. 1 Credit.
Seminar for Electrical & Computer Engineering; required of all doctoral students who have not passed the qualifying exam. Repeatable course.
Area: Engineering, Natural Sciences

EN.520.601. Introduction to Linear Systems Theory. 3 Credits.
A beginning graduate course in multi-input multi-output, linear, time-invariant systems. Topics include state-space and input-output representations; solutions and their properties; multivariable poles and zeros; reachability, observability and minimal realizations; stability; system norms and their computation; linearization techniques. Recommended Course Background: Undergraduate courses in control systems and linear algebra.Students cannot take EN.520.601 if they have already taken the equivalent courses EN.530.616 OR EN.580.616
Prerequisite(s): Students cannot take EN.520.601 if they have already taken EN.580.616 OR EN.530.616.

EN.520.603. Introduction to Optical Instruments. 3 Credits.
This course is intended to serve as an introduction to optics and optical instruments that are used in engineering, physical, and life sciences. The course covers first basics of ray optics with the laws of refraction and reflection and goes on to description of lenses, microscopes, telescopes, and imaging devices. Following that basics of wave optics are covered, including Maxwell equations, diffraction and interference. Operational principles and performance of various spectrometric and interferometric devices are covered including both basics (monochromatic, Fabry-Perot and Michelson interferometers), and advanced techniques of near field imaging, laser spectroscopy, Fourier domain spectroscopy, laser Radars and others.
Area: Engineering

EN.520.607. Introduction to the Physics of Electronic Devices. 3 Credits.
This course is designed to develop and enhance the understanding of the basic physical processes taking place in the electronic and optical devices and to prepare students for taking classes in semiconductor devices and circuits, optics, lasers, and microwaves devices, as well as graduate courses. Both classical and quantum approaches are used. Specific topics include theory of molecular bonding; basics of solid state theory; mechanical, transport, magnetic, and optical properties of the metals; semiconductors; and dielectrics.
Prerequisite(s): Students may earn credit for EN.520.607 or EN520.407 but not both.
Area: Engineering

EN.520.612. Machine Learning for Signal Processing. 3 Credits.
This course will focus on the use of machine learning theory and algorithms to model, classify and retrieve information from different kinds of real world complex signals such as audio, speech, image and video. Recommended Course Background: AS.110.201, EN.553.310, and EN.520.435.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;Credit may only be earned for EN.520.412 or EN.520.612.
Area: Engineering

EN.520.613. Advanced Topics in Optical Medical Imaging. 3 Credits.
The course will review the recent advances in photonics technologies for medical imaging and sensing. The course is designed for graduate students with a back ground in optics and engineering. The main topics for the course are: Light Source and Devices for Biomedical Imaging; Fluorescence, Raman, Rayleigh Scatterings; Optical Endoscopy and Virtual biopsy; Novel imaging contrast dyes, nanoparticles, and optical clearing reagents; Label-free optical technologies in clinical applications; Neurophotonics and Optogenetics.

EN.520.614. Image Processing & Analysis. 3 Credits.
The course covers fundamental methods for the processing and analysis of images and describes standard and modern techniques for the understanding of images by humans and computers. Topics include elements of visual perception, sampling and quantization, image transforms, image enhancement, color image processing, image restoration, image segmentation, and multiresolution image representation. Laboratory exercises demonstrate key aspects of the course.Recommended Prerequisite: EN.520.214 or equivalent
Area: Engineering

EN.520.615. Image Processing & Analysis II. 3 Credits.
The course covers fundamental methods for the processing and analysis of images and describes standard and modern techniques for the understanding of images by humans and computers. Topics include elements of visual perception, sampling and quantization, image transforms, image enhancement, color image processing, image restoration, image segmentation, and multiresolution image representation. Laboratory exercises demonstrate key aspects of the course. Grad students only.
Area: Engineering

EN.520.616. Processing of Audio and Visual Signals. 3 Credits.
This course consists of two parts. The lecture component of this course is covered by attending EN.520.315. Concurrently, on the more advanced graduate level, there is an additional requirement of critical analysis of the material covered, and the hands-on homework complementing the lectures. Recommended Course Background: EN.520.214 (or EN.580.222) or consent of the instructor.

EN.520.617. Computation for Engineers. 3 Credits.
Designing algorithms in a finite precision environment that are accurate, fast, and memory efficient is a challenge that many engineers must face. This course will provide students with the tools they need to meet this challenge. Topics include floating point arithmetic, rounding and discretization errors, problem conditioning, algorithm stability, solving systems of linear equations and least-squares problems, exploiting matrix structure, interpolation, finding zeros and minima of functions, computing Fourier transforms, derivatives, and integrals. Matlab is the computing platform.
Area: Engineering

EN.520.621. Introduction To Nonlinear Systems. 3 Credits.
Nonlinear systems analysis techniques: phase-plane, limit cycles, harmonic balance, expansion methods, describing function. Liapunov stability. Popov criterion. Recommended Course Background: EN.520.601 or equivalent.
Area: Engineering, Natural Sciences

EN.520.622. Principles of Complex Networked Systems. 3 Credits.
By employing fundamental concepts from diverse areas of research, such as statistics, signal processing, biophysics, biochemistry, cell biology, and epidemiology, this course introduces a multidisciplinary and rigorous approach to the modeling and computational analysis of complex interaction networks. Topics to be covered include: overview of complex nonlinear interaction networks and their applications, graph-theoretic representations of network topology and stoichiometry, stochastic modeling of dynamic processes on complex networks and master equations, Langevin, Poisson, Fokker-Plank, and moment closure approximations, exact and approximate Monte Carlo simulation techniques, time-scale separation approaches, deterministic and stochastic sensitivity analysis techniques, network thermodynamics, and reverse engineering approaches for inferring network models from data.

EN.520.623. Medical Image Analysis. 3 Credits.
Graduate version of 520.433. This course covers the principles and algorithms used in the processing and analysis of medical images. Topics include, interpolation, registration, enhancement, feature extraction, classification, segmentation, quantification, shape analysis, motion estimation, and visualization. Analysis of both anatomical and functional images will be studied and images from the most common medical imaging modalities will be used. Projects and assignments will provide students experience working with actual medical imaging data.
Prerequisite(s): Student may earn credit for 520.433 or 520.623, but not both.;EN.520.432 OR EN.580.472 AND EN.550.310 OR EN.550.311

EN.520.624. Integrated Photonics. 3 Credits.
This course gives an introduction to integrated photonics. Topics include: material platforms, fabrication approaches, devices and device operation, numerical modeling, nonlinear processes, and applications. Devices discussed include waveguides, resonators, sensors, modulators, detectors, lasers and amplifiers. Recommended Course Background: EN.520.219-EN.520.220, EN.520.495, or equivalent.
Area: Engineering, Natural Sciences

EN.520.627. Photovoltaics and Energy Devices. 3 Credits.
This course provides an introduction to the science of photovoltaics and related energy devices. Topics covered include basic concepts in semiconductor device operation and carrier statistics; recombination mechanisms; p-n junctions; silicon, thin film, and third generation photovoltaic technologies; light trapping; and detailed balance limits of efficiency. Additionally, thermophotovoltaics and electrical energy storage technologies are introduced. A background in semiconductor device physics (EN.520.485, or similar) is recommended.

EN.520.628. Satellite Communication System. 3 Credits.
This course presents the fundamentals of satellite communications link design and an in-depth treatment of practical considerations. Existing commercial, civil, and military systems are described and analyzed.Topics include satellite orbits, link analysis, antenna and payload design, interference and propagation effects, modulation techniques, coding, multiple access, and Earth station design. The impact of new technology on future systems in this dynamic field is discussed.Recommended Course Background: Communication Systems Engineering or equivalent or permission of the instructor.

EN.520.629. Networked Dynamical Systems. 3 Credits.
Networks and dynamics are pervasive in our world today. Power systems, the Internet, social networks, and biological systems are only a few of the numerous scenarios in which objects or individuals can affect -and be affected by- other members of a large group. This course examines modeling, analysis and design of networked dynamical systems -i.e., dynamic entities interconnected by a network- as well as various applications of such systems in science and engineering. Topics covered include (algebraic) graph theory, basic models of networked dynamical systems, continuous-time and discrete-time distributed averaging (consensus), coordination algorithms (rendezvous, formation, flocking, and deployment), and distributed algorithm computation and optimization over networks. Some of the motivating applications that will be analyzed are robotic coordination, coupled oscillators, social networks, web PageRank, sensor networks, power grids, and epidemics.Recommended Course Background: Linear Algebra (AS.110.201), Control Systems (EN.520.353), or equivalents, basic Matlab skills, and sufficient mathematical maturity.

EN.520.631. Ultrasound and Photoacoustic Beamforming. 3 Credits.
This course will discuss basic principles of ultrasound and photoacoustic imaging and provide an in-depth analysis of the beamforming process required to convert received electronic signals into a usable image. We will cover basic beamforming theory and apply it to real data. The course will culminate with student projects to design and implement a new beamformer derived from the principles taught in class. Recent projects have focused on the emerging use of deep learning to form a new class of ultrasound and photoacoustic images. Recommended background for students interested in deep learning projects: machine learning (EN.601.475), deep learning (EN.520.438/638 or EN.601.482/682), or equivalent.

EN.520.632. Medical Imaging Systems. 3 Credits.
This course provides students with an introduction to the physics, instrumentation, and signal processing methods used in general radiography, X-ray computed tomography, ultrasound imaging, magnetic resonance imaging, and nuclear medicine. The primary focus is on the methods required to reconstruct images within each modality from a signals and systems perspective, with emphasis on the resolution, contrast, and signal-to-noise ratio of the resulting images. Students will additionally engage in hands-on activities to reconstruct medical images from raw data.
Area: Engineering

EN.520.633. Intro To Robust Control. 3 Credits.
The subject of this course is robust analysis and control of multivariable systems. Topics include system analysis (small gain arguments, integral quadratic constraints); parametrization of stabilizing controllers; H_{∞} optimization based robust control design; and LTI model order reduction (balanced truncation, Hankel reduction). Recommended Course Background: EN.520.601 or EN.530.616 or EN.580.616
Area: Engineering

EN.520.634. Modern Biomedical Imaging Instrumentation and Techniques. 3 Credits.
An intermediate biomedical imaging course covering modern biomedical imaging instrumentation and techniques as applied to diagnostic radiology and other biomedical applications. It includes recent advances in various biomedical imaging modalities, multi- modality imaging and molecular imaging. The course is team taught by experts in the respective fields and provides a broad based knowledge of modern biomedical imaging to prepare students for graduate studies and research in biomedical imaging. Also, the course will offer tours and practical experience with modern biomedical imaging equipments in clinical and research settings. Co-listed with EN.580.473/773.Background in EN.520.432 or EN.580.472
Prerequisite(s): Students may not have taken EN.520.434.

EN.520.635. Digital Signal Processing. 3 Credits.
Methods for processing discrete-time signals. Topics include signal and system representations, z- transforms, sampling, discrete Fourier transforms, fast Fourier transforms, digital filters.
Area: Engineering

EN.520.636. Feedback Control in Biological Signaling Pathways. 3 Credits.
This course considers examples of the use of feedback control in engineering systems and looks for counterparts in biological signaling networks. To do this will require some knowledge of mathematical modeling techniques in biology, so a part of the course will be devoted to this.

EN.520.637. Foundations of Reinforcement Learning. 3 Credits.
The course will provide a rigorous treatment of reinforcement learning by building on the mathematical foundations laid by optimal control, dynamic programming, and machine learning. Topics include model-based methods such as deterministic and stochastic dynamic programming, LQR and LQG control, as well as model-free methods that are broadly identified as Reinforcement Learning. In particular, we will cover on and off-policy tabular methods such as Monte Carlo, Temporal Differences, n-step bootstrapping, as well as approximate solution methods, including on- and off-policy approximation, policy gradient methods, including Deep Q-Learning. The course has a final project where students are expected to formulate and solve a problem based on the techniques learned in class.
Area: Engineering

EN.520.638. Deep Learning. 3 Credits.
Deep Learning is emerging as one of the most successful tools in machine learning for feature learning and classification. This course will introduce students to the basics of Neural Networks and expose them to some cutting-edge research. In particular, this course will provide a survey of various deep learning-based architectures such as autoencoders, recurrent neural networks and convolutional neural networks. We will discuss merits and drawbacks of available approaches and identify promising avenues of research in this rapidly evolving field. Various applications related to computer vision and biometrics will be studied. The course will include a project, which will allow students to explore an area of Deep Learning that interests them in more depth.Recommended Course Background: EN.520.435, EN.601.220, and EN.553.420
Area: Engineering

EN.520.639. Communication Systems Engineering. 3 Credits.
is course provides an overview of analog communications and presents the theory and applications relevant to modern digital communication systems. The course coversconcepts in random signal analysis, lossless ad lossy source coding, quantization, analog and digital modulation schemes, synchronization, channels characterization andcapacity, optimum receivers, and adaptive equalization. We also discuss modern communication techniques related to adaptive antenna array signal processing and systemsincluding SISO, SIMO, MISO and MIMO.
Area: Engineering

EN.520.644. FPGA Synthesis Lab. 3 Credits.
An advanced laboratory course in the application of FPGA technology to information processing, using VHDL synthesis methods for hardware development. The student will use commercial CAD software for VHDL simulation and synthesis, and implement their systems in programmable XILINX 20,000 gate FPGA devices. The lab will consist of a series of digital projects demonstrating VHDL design and synthesis methodology, building up to final projects at least the size of an 8-bit RISC computer. Projects will encompass such things as system clocking, flip-flop registers, state-machine control, and arithmetic. The students will learn VHDL methods as they proceed through the lab projects, and prior experience with VHDL is not a prerequisite.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.645. Audio Signal Processing. 3 Credits.
This course gives a foundation in current audio and speech technologies, and covers techniques for sound processing by processing and pattern recognition, acoustics, auditory perception, speech production and synthesis, speech estimation. The course will explore applications of speech and audio processing in human computer interfaces such as speech recognition, speaker identification, coding schemes (e.g. MP3), music analysis, noise reduction. Students should have knowledge of Fourier analysis and signal processing.
Area: Engineering

EN.520.646. Wavelets & Filter Banks. 3 Credits.
This course serves as an introduction to wavelets, filter banks, multirate signal processing, and time-frequency analysis. Topics include wavelet signal decompositions, bases and frames, QMF filter banks, design methods, fast implementations, and applications. Recommended Course Background: EN.520.435, AS.110.201, C/C++ and Matlab programming experience.

EN.520.647. Information Theory. 3 Credits.
This course will address some basic scientific questions about systems that store or communicate information. Mathematical models will be developed for (1) the process of error-free data compression leading to the notion of entropy, (2) data (e.g. image) compression with slightly degraded reproduction leading to rate-distortion theory and (3) error-free communication of information over noisy channels leading to the notion of channel capacity. It will be shown how these quantitative measures of information have fundamental connections with statistical physics (thermodynamics), computer science (string complexity), economics (optimal portfolios), probability theory (large deviations), and statistics (Fisher information, hypothesis testing).
Prerequisite(s): Students can earn credit for either 520.447 or 520.647, not both.
Area: Engineering

EN.520.648. Compressed Sensing and Sparse Recovery. 3 Credits.
Sparsity has become a very important concept in recent years in applied mathematics, especially in mathematical signal and image processing, as in inverse problems. The key idea is that many classes of natural signals can be described by only a small number of significant degrees of freedom. This course offers a complete coverage of the recently emerged field of compressed sensing, which asserts that, if the true signal is sparse to begin with, accurate, robust, and even perfect signal recovery can be achieved from just a few randomized measurements. The focus is on describing the novel ideas that have emerged in sparse recovery with emphasis on theoretical foundations, practical numerical algorithms, and various related signal processing applications. Recommended Course Background: Undergraduate linear algebra and probability.

EN.520.649. Introduction to Radar Systems. 3 Credits.
This course introduces the fundamental concepts of the modern radar system architecture and design. Topics include the major subsystems and functions of a typical radar, the radar range equation and its different forms, radar cross section, signal to noise ratio, and radar modes. We will also discuss antennas, propagation, pulse compression, detection, tracking and many other general radar topics.

EN.520.651. Random Signal Analysis. 4 Credits.
The content for EN.520.651 has been revised with greater emphasis on graphical models, parameter estimation and posterior inference. Topics include probability theory, random variables/vectors, hypothesis testing, parameter estimation, directed and undirected graphical models, the EM algorithm, deterministic and stochastic approximations for EM, Markov chains and random sequences. Additional material may be covered as appropriate. The class is theoretical in nature; new concepts are presented via formula derivations and example problems. Homework assignments may require familiarity with Matlab (or an equivalent computational software).

EN.520.652. Filtering and Smoothing. 3 Credits.
This course is intended to give students an opportunity to do directed research in algorithm development that culminates in a MATLAB program. Students will learn about extracting signals from noise using statistical and non-statistical models. Topics include Kalman filtering, smoothing, interpolation (upsampling), spline fitting, and the numerical linear algebra issues that impact these problems. Emphasis is on fast, compact, stable algorithms. The grade is based on the term project and occasional homework. There are no examinations. Class attendance is mandatory.

EN.520.654. Control Systems Design. 3 Credits.
Classical and modern control systems design methods. Topics include formulation of design specifications, classical design of compensators, state variable and observer based feedback. Computers are used extensively for design, and laboratory experiments are included.
Area: Engineering

EN.520.656. Data Smoothing Using Machine Learning. 3 Credits.
All measurements contain errors (noise). Before the measurements are used, they should be passed through a noise reduction filter. When the noise level is unknown, the filter can be designed using a machine learning method called cross-validation. This course will investigate algorithmic approaches to data smoothing using cross-validation. Students will complete several Matlab projects.
Area: Engineering

EN.520.657. Design of Biomedical Instruments and Systems. 3 Credits.
The purpose of this course is to teach the students principles of product design for the biomedical market. From an idea to a product and all the stages in-between.The course material will include identification of the need, market survey, patents. Funding sources and opportunities, Regulatory requirements, Reimbursement codes, Business models). Integration of the system into the clinical field. system connectivity. Medical information systems. Medical standards (DICOM, HL-7, ICD, Medical information bus). How to avoid mistakes in system design and in system marketing. Entrepreneurship.The course participants will be divided to groups of 2-3 students each. Each group will be acting as a start-up company throughout the whole semester. Each group will need to identify a need. This can be done by meeting and interviewing medical personnel, at the Johns Hopkins Medical campus or other hospitals, clinics, HMOs, assisted living communities or other related to the medical world. The proposed medical instrument or system can be a combination of instrument and software.Each week, there will be a lecture devoted to the principal subjects mentioned above. Afterwards the students will present their ideas and progress to all class participants. There will be an open discussion for each of the projects. The feedback from class will help the development of the product. Each presentation, document, survey or paper will be kept in the course cloud which will have a folder for each of the groups. The material gathered in this folder will be built gradually throughout the semester. Eventually it will become the product blueprint.At the last week of the semester, the groups will present their product to a panel of experts involved with the biotech industry, in order to “convince” them to invest in their project.Previous years’ projects are listed in this website: (https://jhuecepdl.bitbucket.io).
Area: Engineering

EN.520.660. The Art of Error Control Coding. 3 Credits.
Error control coding is the study and practice of detecting and/or correcting errors that occur in the transmission of digital information over a noisy communication channel, the transferal of information to and from memory and mass storage in a computer, or in any other application where random processes corrupt information. The student will study encoders and decoders for the most important codes in current use and will confront realistic problems in the use of coding. The course will comprise lectures, discussions, and projects.
Area: Engineering, Quantitative and Mathematical Sciences

EN.520.662. Leading Innovation Design Team. 3 Credits.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first-hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.edu

EN.520.663. Leading Innovation Design Team. 3 Credits.
Project design course that Complements and/or Builds on Core Knowledge Relevant to Electrical & Computer Engineering with emphasis on multidisciplinary projects. All Projects will be sponsored, have clearly defined objectives, and must yield a Tangible Result at Completion. Project duration can vary between a minimum of 2 semesters and a maximum of 5 years. This course will afford the students the opportunity to use their creativity to innovative and to master critical skills such as: customer/user discovery and product specifications; concept development; trade study; systems engineering and design optimization; root cause; and effective team work. The students will also experience first-hand the joys and challenges of the professional world. The course will be actively managed and supervised to represent the most effective industry practices with the instruction team, including guest speakers, providing customized lectures, technical support, and guidance. In addition, the students will have frequent interactions with the project sponsor and their technical staff. Specific projects will be listed on ece.jhu.edu
Prerequisite(s): Students may receive credit for only one of the following courses; EN.520.251, EN.520.463 OR EN.520.663.;Laboratory Safety Introductory Course available in MyLearning prior to registration. The course is accessible from the Education tab through the portal my.jh.edu. Please note that this requirement is not applicable to new students registering for their first semester at Hopkins.
Area: Engineering

EN.520.665. Machine Perception. 3 Credits.
This course will cover topics such as Marr-Hildreth and Canny edge detectors, local representations (SIFT, LBP), Markov random fields and Gibbs representations, normalized cuts, shallow and deep neural networks for image and video analytics, shape from shading, Make 3D, stereo, and structure from motion.
Area: Engineering

EN.520.666. Information Extraction. 3 Credits.
Introduction to statistical methods of speech recognition (automatic transcription of speech) and understanding. The course is a natural continuation of EN.601.465 but is independent of it. Topics include elementary probability theory, hidden Markov models, and n-gram models using maximum likelihood, Bayesian and discriminative methods, and deep learning techniques for acoustic and language modeling.Recommended Course Background: EN.550.310 AND EN.600.120 or equivalent, expertise in Matlab or Python programming.

EN.520.667. Dynamic Implicit Surfaces. 3 Credits.
Course will cover dynamic implicit surfaces that arise in a number of modeling situations where the boundary is implicit. We will discuss a number of techniques used to generate these models, including level set methods and the phase field approach.

EN.520.670. Infrared Sensing & Technologies. 3 Credits.
Infrared technologies have evolved over the last sixty, primarily driven by defense applications and needs but have recently perforated into various non-defense markets. It remains critical to many military systems and increasing to autonomous systems in general. This course is intended as an overview of the various technologies that make up an infrared sensor system, it will include some historical perspectives as well as the state of the art and will emphasize the various tradeoffs involved in designing a system for particular applications. In particular, it will cover the following topics that represent the main components: optics, detectors, readout integrated circuits (ROIC) including digital designs, the various wavelength (SWIR, MWIR, LWIR), testing and calibration, image and signal processing, and applications. The course structure will involve lectures, labs, and final project. Lectures will involve guest speakers that are subject matter experts on the various topics.
Area: Engineering

EN.520.671. Speech Technologies Reading Group. 1 Credit.
Reading Group that explores novel algorithms and papers on speech technologies

EN.520.673. Magnetic Resonance in Medicine. 3 Credits.
This course provides a wide-ranging introduction to the physics and principles of magnetic resonance imaging (MRI). Topics include the resonance phenomenon, relaxation, signal formation, spatial localization, image contrast, hardware, signal processing, and image reconstruction. MATLAB simulation exercises will demonstrate key aspects of MRI and a laboratory component using the clinical MRI systems at the School of Medicine will reinforce concepts learned in class. Textbook "Principles of Magnetic Resonance Imaging" by D. Nishimura (from www.lulu.com) should be obtained before the start of the course. Recommended Course Background: (EN.520.434 or EN.580.473) or (EN.520.432 or EN.580.472). Co-listed with EN.580.476 and EN.580.673.

EN.520.678. Biomedical Photonics. 3 Credits.
This course will cover the basic optics principles including geometric, beam and wave description of light. The course will also cover the basic generation and detection techniques of light and the principles of optical imaging and spectroscopy. After the basis is established, we will focus on some commonly employed optical techniques and tools for biomedical research including various optical microscopy technologies, fiber optics, Raman spectroscopy, Fluorescence (lifetime), FRAT, FRET and FCS. The recent development in tissue optics, biomedical optical imaging/spectroscopy techniques (such as OCT, multiphoton fluorescence and harmonics microscopy, Structured Illumination, light scattering, diffuse light imaging and spectroscopy, optical molecular imaging, photo-acoustic imaging) will also be discussed. Representative biomedical applications of translational biomedical photonics technologies will be integrated into the corresponding chapters.
Area: Engineering

EN.520.680. Speech and Auditory Processing by Humans and Machines. 3 Credits.
The course relevant to building advanced systems for information extraction from speech and auditory signals. It introduces some relevant historical efforts for information processing of speech and audio signals and basic concepts of human auditory perception and human production and perception of speech. The main goal of the course is in implementation of relevant knowledge of human speech information processing in engineering systems for information extraction from speech signals, emphasizing power of the modern data-guided machine learning techniques. Basic knowledge of signal processing is assumed and the previous completion of the EN.520.445 or EN.520.645 is beneficial.

EN.520.682. Introduction to Lasers. 3 Credits.
This course covers the basic principles of laser oscillation. Specific topics include propagation of rays and Gaussian beams in lens-like media, optical resonators, spontaneous and stimulated emission, interaction of optical radiation and atomic systems, conditions for laser oscillation, homogeneous and inhomogeneous broadening, gas lasers, solid state lasers, Q-switching and mode locking of lasers.Recommended Course Background: EN.520.219 and EN.520.220

EN.520.683. Bio-Photonics Laboratory. 3 Credits.
This laboratory course involves designing a set of basic optical experiments to characterize and understand the optical properties of biological materials. The course is designed to introduce students to the basic optical techniques used in medicine, biology, chemistry and material sciences. Graduate version of EN.520.483
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.685. Advanced Semiconductor Devices. 3 Credits.
This course is designed to develop and enhance the understanding of the operating principles and performance characteristics of the modern semiconductor devices used in high speed optical communications, optical storage and information display. The emphasis is on device physics andfabrication technology. The devices include heterojunction bipolar transistors, high mobility FET's, semiconductor lasers, laser amplifiers, light-emitting diodes, detectors, solar cells and others.
Prerequisite(s): Students can only take EN.520.485 or EN.520.685, not both.
Area: Engineering, Natural Sciences

EN.520.686. Physics of Semiconductor Electronic Devices. 3 Credits.
The course is designed to develop and enhance the understanding of the physical principles of modern semiconductor electronic and opto-electronic devices. The course starts with the basics of band structure of solid with emphasis on group IV and III-V semiconductors as well as two dimensional semiconductors like graphene. It continues with the statistics of carriers in semiconductors and continues to electronic transport properties, followed by optical properties. The course goes on to investigate the properties of two dimensional electronic gas. The second part of the course describes operational principles of bipolar and unipolar transistors, light emitting diodes, photodetectors, and quantum devices.
Prerequisite(s): Students may earn credit for EN.520.486 or EN.520.686, but not both.
Area: Engineering

EN.520.691. CAD Design of Digital VLSI Systems I (Grad). 3 Credits.
Graduate students only.
Area: Engineering

EN.520.692. Mixed-Mode VLSI Systems. 3 Credits.
Silicon models of information and signal processing functions, with implementation in mixed analog and digital CMOS integrated circuits. Aspects of structured design, scalability, parallelism, low power consumption, and robustness to process variations. Topics include digital-to-analog and analog-to-digital conversion, delta-sigma modulation, bioinstrumentation, and adaptive neural computation. The course includes a VLSI design project. Recommended Course Background: EN.521.491 or equivalent.

EN.520.700. Masters Research. 3 - 10 Credits.
Independent research for masters students

EN.520.701. Current Topics in Language and Speech Processing. 1 Credit.
This biweekly seminar will cover a broad range of current research topics in human language technology, including automatic speech recognition, natural language processing and machine translation. The Tuesday seminars will feature distinguished invited speakers, while the Friday seminars will be given by participating students. A minimum of 75% attendance and active participation will be required to earn a passing grade. Grading will be S/U.

EN.520.702. Current Topics in Language and Speech Processing. 1 Credit.
This biweekly seminar will cover a broad range of current research topics in human language technology, including automatic speech recognition, natural language processing and machine translation. The Tuesday seminars will feature distinguished invited speakers, while the Friday seminars will be given by participating students. A minimum of 75% attendance and active participation will be required to earn a passing grade. Cross-listed with Computer Science. Grading will be S/U.
Area: Engineering

EN.520.735. Sensory Information Processing. 3 Credits.
Analysis of information processing in biological sensory organs and in engineered microsystems using the mathematical tools of communication theory. Natural or synthetic structures are modeled as microscale communication networks implemented under physical constraints, such as size and available energy resources and are studied at two levels of abstraction. At the information processing level we examine the functional specification, while at the implementation level we examine the physical specification and realization. Both levels are characterized by Shannon's channel capacity, as determined by the channel bandwidth, the signal power, and the noise power. The link between the information processing level and the implementation level of abstraction is established through first principles and phenomenological otherwise, models for transformations on the signal, constraints on the system, and noise that degrades the signals.

EN.520.738. Advanced Electronic Lab Design. 3 Credits.
This course is the graduate expansion of the EN.520.448 Electronic Design Lab, which is an advanced laboratory course in which teams of students design, build, test and document application specific information processing microsystems. Semester long projects range from sensors/actuators, mixed signal electronics, embedded microcomputers, algorithms and robotics systems design. Demonstration and documentation of projects are important aspects of the evaluation process. For this graduate expansion, all projects will be based on recently published research from IEEE Transactions. The students will be required to fully research, analyze, implement and demonstrate their chosen topic. The emphasis will be on VLSI microsystems, although other topics will also be considered. Open to graduate students only.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.744. Advanced Topics in Signal Processing and Applied Machine learning for Next Generation Radar. 3 Credits.

EN.520.746. Seminar: Medical Image Analysis. 1 Credit.
This weekly seminar will focus on research issues in medical image analysis, including image segmentation, registration, statistical modeling, and applications. It will also include selected topics relating to medical image acquisition, especially where they relate to analysis. The purpose of the course is to provide the participants with a background in current research in these areas, as well as to promote greater awareness and interaction between multiple research groups within the University. The format of the course is informal. It will meet weekly for approximately 1.5 hours. Students will read selected papers and will be assigned on a rotating basis to lead the discussion.Co-listed as EN.601.856.

EN.520.762. Emerging Models of Computation. 3 Credits.
Advanced seminar course with topics in emerging models of computation. This year (Spring 2019) the course focuses on neurotrophic machine learning, event-based spike based processing and neural computation . The students will learn and use Brian and PyNN for a project in the class. (Permission of instructor required)
Area: Engineering

EN.520.773. Advanced Topics In Microsytem Fabrication. 4 Credits.
Graduate-level course on topics that relate to microsystem integration of complex functional units across different physical scales from nano to micro and macro. Course comprises of laboratory work and accompanying lectures that cover silicon oxidation, aluminum evaporation, photoresist deposition, photolithography, plating, etching, packaging, design and analysis CAD tools, and foundry services. Topics will include emerging fabrication technologies, micro-electromechanical systems, nanolithography, nanotechnology, soft lithography, self-assembly, and soft materials. Discussion will also include biological systems as models of microsystem integration and functional complexity. Perm. Required.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.774. Advanced Topics in Electrical and Computer Engineering. 3 Credits.
Course content varies by instructor and topic. The major focus of this course is to train graduate students in developing or increasing research ability related to new and advanced concepts in electrical engineering. For example, these concepts may include advanced techniques in signal processing and communications, high performance computing, real-time computing and advanced parallel system architectures.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.

EN.520.788. Biomedical Photonics II. 3 Credits.
This course serves as the continuation of 580.678(520.678) (Biomedical Photonics Part 1). It will cover the advanced topics on biomedical photonics, including (but not limited to) light scattering (Rayleigh and Mie scattering), photon diffusion, polarization (birefringence), fluorescence, lifetime measurements, confocal microscopy, optical coherence tomography, nonlinear microscopy, and super-resolution microscopy. Representative biomedical applications of some of these technologies will be integrated into the relevant chapters. If the lab space becomes available, we will also offer a hand-on lab section (optional) for students to design and build an imaging instrument.Recommended Background: Biomedical Photonics (580.678/520.678), or equivalent background on optics.

EN.520.800. Independent Study. 1 - 3 Credits.
Individual, guided study under the direction of a faculty member in the department. May be taken either term by graduate students.

EN.520.801. Dissertation Research. 3 - 20 Credits.

EN.520.802. Dissertation Research. 3 - 20 Credits.

EN.520.890. Independent Study-Summer. 1 - 3 Credits.

Cross Listed Courses

Biomedical Engineering

EN.580.472. Medical Imaging Systems. 3 Credits.
An introduction to the physics, instrumentation, and signal processing methods used in general radiography, X-ray computed tomography, ultrasound imaging, magnetic resonance imaging, and nuclear medicine. The primary focus is on the methods required to reconstruct images within each modality, with emphasis on the resolution, contrast, and signal-to-noise ratio of the resulting images. Cross-listed with Neuroscience and Electrical and Computer Engineering (EN.520.432).
Prerequisite(s): EN.580.222 OR EN.520.214
Area: Engineering

Computer Science

EN.601.479. Representation Learning. 3 Credits.
Often the success of a machine learning project depends on the choice of features used. Machine learning has made great progress in training classification, regression and recognition systems when "good" representations, or features, of input data are available. However, much human effort is spent on designing good features which are usually knowledge-based and engineered by domain experts over years of trial and error. A natural question to ask then is "Can we automate the learning of useful features from raw data?" Representation learning algorithms such as principal component analysis aim at discovering better representations of inputs by learning transformations of data that disentangle factors of variation in data while retaining most of the information. The success of such data-driven approaches to feature learning depends not only on how much data we can process but also on how well the features that we learn correlate with the underlying unknown labels (semantic content in the data). This course will focus on scalable machine learning approaches for learning representations from large amounts of unlabeled, multi-modal, and heterogeneous data. We will cover topics including deep learning, multi-view learning, dimensionality reduction, similarity-based learning, and spectral learning. Students may receive credit for 600.479 or 600.679 but not both. [Analysis or Applications] Required course background: machine learning or basic probability and linear algebra.
Area: Engineering

General Engineering

EN.500.112. Gateway Computing: JAVA. 3 Credits.
This course introduces fundamental programming concepts and techniques, and is intended for all who plan to develop computational artifacts or intelligently deploy computational tools in their studies and careers. Topics covered include the design and implementation of algorithms using variables, control structures, arrays, functions, files, testing, debugging, and structured program design. Elements of object-oriented programming. algorithmic efficiency and data visualization are also introduced. Students deploy programming to develop working solutions that address problems in engineering, science and other areas of contemporary interest that vary from section to section. Course homework involves significant programming. Attendance and participation in class sessions are expected.
Prerequisite(s): Students may not have earned credit in courses: EN.500.113 OR EN.500.114 OR EN.510.202 OR EN.530.112 OR EN.580.200 OR EN.601.107.
Area: Engineering

EN.500.745. Seminar in Computational Sensing and Robotics. 1 Credit.
Seminar series in robotics. Topics include: Medical robotics, including computer-integrated surgical systems and image-guided intervention. Sensor based robotics, including computer vision and biomedical image analysis. Algorithmic robotics, robot control and machine learning. Autonomous robotics for monitoring, exploration and manipulation with applications in home, environmental (land, sea, space), and defense areas. Biorobotics and neuromechanics, including devices, algorithms and approaches to robotics inspired by principles in biomechanics and neuroscience. Human-machine systems, including haptic and visual feedback, human perception, cognition and decision making, and human-machine collaborative systems.Cross-listed Mechanical Engineering, Computer Science, Electrical and Computer Engineering, and Biomedical Engineering.

Mechanical Engineering

EN.530.421. Mechatronics. 3 Credits.
Students from various engineering disciplines are divided into groups of two to three students. These groups each develop a microprocessor-controlled electromechanical device, such as a mobile robot. The devices compete against each other in a final design competition. Topics for competition vary from year to year. Class instruction includes fundamentals of mechanism kinematics, creativity in the design process, an overview of motors and sensors, and interfacing and programming microprocessors.
Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.;EN.530.420 OR EN.520.240 OR EN.520.340 or permission of the instructor.
Area: Engineering

EN.530.616. Introduction to Linear Systems Theory. 3 Credits.
A beginning graduate course in multi-input multi-output, linear, time-invariant systems. Topics include state-space and input-output representations; solutions and their properties; multivariable poles and zeros; reachability, observability and minimal realizations; stability; system norms and their computation; linearization techniques.Students cannot take EN.530.616 if they have already taken the equivalent courses EN.520.601 OR EN.580.616. No audit option.
Prerequisite(s): Students cannot take EN.530.616 if they have already taken EN.520.601 OR EN.580.616.

For current faculty and contact information go to http://www.ece-jhu.org/index.php/people (http://www.ece-jhu.org/index.php/people/)