

ELECTRICAL ENGINEERING

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Electrical Engineering broadly encompasses disciplines such as microelectronics, photonics, computer engineering, signal processing, control systems, and communications. Three electrical engineering degree programs are offered, as well as a joint degree between the electrical engineering and computer science departments.

1. The **B.S. in Electrical Engineering**, accredited by the Engineering Accreditation Commission of ABET, Inc., is the flagship degree program and is the most challenging program in electrical engineering. This program is appropriate for highly motivated students who are interested in entering the engineering profession, and who wish for a flexible enough program to consider a variety of other career paths.

Upon graduation, Yale's B.S. Electrical Engineering (ABET) students are expected to achieve "student outcomes" as defined by ABET and the program. The Electrical Engineering major produces graduates who demonstrate: (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics; (2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors; (3) an ability to communicate effectively with a range of audiences; (4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts; (5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives; (6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions; (7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

2. The **B.S. in Engineering Sciences (Electrical)** provides similar technical exposure and equivalent rigor as the ABET program, while retaining the flexibility for students to take a broader range of courses than those mandated by the ABET curriculum. The B.S. in Engineering Sciences (Electrical) is suitable for careers in technology and is a popular choice for those choosing academic, industrial, or entrepreneurial career paths.

3. The **B.A. in Engineering Sciences (Electrical)** is suitable for careers outside of technology, including managerial, financial, and entrepreneurial career options.

4. The fourth program is a joint **B.S. in Electrical Engineering and Computer Science**, which offers a unique blend of electrical engineering and computer science courses that retains the rigor of both fields. This degree is a popular choice for those interested in information technology careers.

The program's educational objectives prepare students for four potential paths. An academic path qualifies graduates to enter a top-tier graduate program conducting research with broad applications or significant consequences, and eventually to teach at an academic or research institution. Graduates following an industrial path can enter a technical path or a managerial path. An entrepreneurial path allows graduates to bring broad knowledge to a startup company, which can deliver a product or service that meets societal needs. Graduates who elect a nontraditional engineering path might complete a professional program in business, law, or medicine, for which their engineering knowledge will be valuable.

PREREQUISITES

All three engineering degree programs require MATH 112 and MATH 115 if applicable, ENAS 151 or MATH 120 or higher, ENAS 130 (CPSC 100 and 112 do not fulfill this requirement), and PHYS 180, 181 or higher (PHYS 170, 171 is acceptable for the B.A. degree). Acceleration credits awarded on entrance can be used to satisfy the MATH 112 and 115 requirements. Students whose preparation exceeds the level of ENAS 151 or MATH 120 are asked to take a higher-level mathematics course instead, such as MATH 250. Similarly, students whose preparation at entrance exceeds the level of PHYS 180, 181 are asked to take higher-level physics courses instead, such as PHYS 200, 201. Students whose programming skills exceed the level of ENAS 130 are asked to take a more advanced programming course instead, such as CPSC 201; consult with the director of undergraduate studies (DUS).

For students in the Class of 2023 and subsequent classes, prerequisites taken Credit/D/Fail may not be counted toward the requirements of the major.

REQUIREMENTS OF THE MAJOR

Because the introductory courses are common to all three degree programs, students do not usually need to make a final choice before the junior year. Each student's program must be approved by the DUS.

B.S. degree program in Electrical Engineering The ABET-accredited B.S. in Electrical Engineering requires, beyond the prerequisites, four term courses in mathematics and science and thirteen term courses covering topics in engineering. These courses include:

1. Mathematics and basic science (four term courses): ENAS 194; MATH 222 or 225; APHY 322 or equivalent; S&DS 238, or S&DS 241, or equivalent.

2. Electrical engineering and related subjects (thirteen term courses): EENG 200, 201, 202, 203, 310, 320, 325, 348, and 481 (the ABET design project senior requirement); and four engineering electives, at least three of which should be at the 400 level. CPSC 365 or CPSC 366, MENG 390, MENG 403, BENG 411, PHYS 430, APHY 458, and all 400-level Computer Science courses qualify as ABET electives. One of EENG 468 or EENG 469, Advanced Special Projects, also qualify as a 400-level elective.

The introductory engineering courses are designed such that they may be taken concurrently in the sophomore year; for example, in the fall term students may take EENG 200 and EENG 202, followed by EENG 201 and EENG 203 in the spring term. These courses may be taken in any order, with the exception of EENG 203, which requires EENG 200 as a prerequisite. In this case, it would be helpful to take ENAS 194 and/or ENAS 130 in the first year.

A sample ABET-accredited B.S. degree schedule for students who have taken the equivalent of one year of calculus in high school (and thus are not required to take MATH 112 and MATH 115) could include:

First Year: EENG 200, EENG 201, ENAS 151, PHYS 180, and PHYS 181
 Sophomore: EENG 202, EENG 203, ENAS 130, ENAS 194, and MATH 222
 Junior: EENG 310, EENG 320, EENG 325, EENG 348, S&DS 238, and 1 elective
 Senior: APHY 322, EENG 481, and 3 electives

A sample schedule for students that enter into the ABET-accredited B.S. major at the sophomore year could include:

First Year: ENAS 151, ENAS 130, ENAS 194, PHYS 180, and PHYS 181
 Sophomore: EENG 200, EENG 201, EENG 202, EENG 203, and MATH 222
 Junior: EENG 310, EENG 320, EENG 325, EENG 348, S&DS 238, and 1 elective
 Senior: APHY 322, EENG 481, and 3 electives

A sample schedule for students who enter into the ABET-accredited B.S. major in the first year (and are required to take MATH 112 and MATH 115) and only seek to fulfill basic distribution requirements with no engineering courses, could be:

First Year: MATH 112, MATH 115, PHYS 180, PHYS 181, and ENAS 130
 Sophomore: ENAS 151, EENG 200, EENG 201, EENG 202, EENG 203, and MATH 222
 Junior: ENAS 194, EENG 310, EENG 320, EENG 325, EENG 348, and S&DS 238
 Senior: APHY 322, EENG 481, and 4 electives

B.S. degree program in Engineering Sciences (Electrical) This program requires fewer technical courses and allows more freedom for work in technical areas outside the traditional electrical engineering disciplines (e.g., biomedical engineering, mechanical engineering, physics, etc.). It requires thirteen technical term courses beyond the prerequisites, specifically: MATH 222 or 225; ENAS 194; EENG 200, 201, 202, 203; EENG 471 or 472 (the senior requirement), or with permission of the instructor and the DUS, 481; and six electives approved by the DUS, at least three of which must be at the 400 level. All electives listed for the ABET-accredited B.S. major qualify as electives for this degree.

For students who have taken the equivalent of one year of calculus in high school (and thus are not required to take MATH 112 and MATH 115), a sample schedule for the B.S. degree in Engineering Science (Electrical) could be:

First Year: EENG 200, EENG 201, ENAS 151, PHYS 180, and PHYS 181
 Sophomore: EENG 202, EENG 203, ENAS 130, ENAS 194, and MATH 222
 Junior: 3 electives
 Senior: EENG 471 and/or EENG 472, and 3 electives

The B.S. degree in Engineering Sciences (Electrical) requires fewer specific courses and 4 fewer courses overall than the ABET-accredited degree. Any of the courses required for the ABET-accredited major qualify as electives for this degree, as well as other courses with substantial electrical engineering context, subject to the approval of the DUS. For students entering the major during the sophomore year, or those that need introductory calculus in their first year, sample schedules are similar to those described for the ABET-accredited degree program, with the differences in the B.S. Engineering Sciences (Electrical) degree applied.

The flexibility during the junior and senior years in the schedule above is often used to accommodate a second major, such as Economics, Applied Physics, Computer Science, Physics, or Mechanical Engineering.

B.A. degree program in Engineering Sciences (Electrical) This program is appropriate for those planning a career in fields such as business, law, or medicine where scientific and technical knowledge is likely to be useful. It requires eight technical term courses beyond the prerequisites, specifically: MATH 222, 225, or ENAS 194; EENG 200, 201, 202, and 471 and/or 472 (the senior requirement); and three approved electives.

Credit/D/Fail For students in the Class of 2023 and subsequent classes, courses taken Credit/D/Fail may not be counted toward the requirements of the major, including the prerequisites.

SENIOR REQUIREMENT

A research or design project carried out in the senior year is required in all three programs and must be approved by the DUS. Students take EENG 471, 472, or 481, present a written report, and make an oral presentation. Arrangements to undertake a project in fulfillment

of the senior requirement must be made by the end of shopping period in the term in which the student will enroll in the course; by this date, a prospectus approved by the intended faculty adviser must be submitted to the DUS.

ADVISING AND APPROVAL OF PROGRAMS

All Electrical Engineering and Engineering Sciences majors must have their programs approved by the DUS. Arrangements to take EENG 471, 472, or 481 are strongly suggested to be made during the term preceding enrollment in the course. Independent research courses (EENG 468 or EENG 469) are graded on a Pass/Fail basis, but one (1) can be counted toward the requirements of the major.

REQUIREMENTS OF THE MAJOR

ELECTRICAL ENGINEERING, B.S.

Prerequisites MATH 112, 115 if needed; ENAS 151 or MATH 120 or higher; ENAS 130; PHYS 180, 181 or higher

Number of courses 17 term courses beyond prereqs, incl senior req

Specific courses required ENAS 194; MATH 222 or 225; APHY 322; S&DS 238 or S&DS 241; EENG 200, 201, 202, 203, 310, 320, 325, 348

Distribution of courses 4 engineering electives, 3 at 400 level

Senior requirement One-term design project (EENG 481)

ENGINEERING SCIENCES (ELECTRICAL), B.S. AND B.A.

Prerequisites *Both degrees* – MATH 112, 115; ENAS 151 or MATH 120 or higher; ENAS 130; *B.S.* – PHYS 180, 181 or higher;

B.A. – PHYS 170, 171 or higher

Number of courses *B.S.* – 13 term courses beyond prereqs, incl senior req; *B.A.* – 8 term courses beyond prereqs, incl senior req

Specific courses required *B.S.* – ENAS 194; MATH 222 or 225; EENG 200, 201, 202, 203; *B.A.* – 1 from ENAS 194, MATH 222, or 225; EENG 200, 201, 202

Distribution of courses *B.S.* – 6 electives approved by DUS, 3 at 400 level; *B.A.* – 3 electives approved by DUS

Senior requirement *B.S.* – one-term research or design project (EENG 471 or 472 or, with permission of DUS, 481); *B.A.* – one-term research or design project (EENG 471 and/or 472)

Electrical engineering (EE) deals with the study and application of electricity, electronics, and electromagnetism, including such topics as digital computers, power engineering, telecommunications, control systems, radio-frequency engineering, signal processing, instrumentation, and microelectronics. Electrical engineers were responsible for inventing much of today's sophisticated technology, such as the Internet, land and air transportation systems, medical devices, and many other modern features of everyday life. Yale electrical engineer graduates are highly respected and sought after for work not only in the engineering profession, but in business, start-up ventures, management consulting, investment banking, venture finance, medicine, and intellectual property law.

Four degree programs allow students to select the level of technical depth appropriate for their individual goals.

1. The B.S. in Electrical Engineering is accredited by the Engineering Accreditation Commission of ABET, Inc., and is the department's most intensive major program. Students are trained for engineering practice, and the curriculum culminates in a major team design project that incorporates engineering standards and realistic constraints. This program is appropriate for highly motivated students who have a strong interest in the engineering profession.
2. The B.S. in Engineering Sciences (Electrical) requires a somewhat smaller number of courses than the ABET-accredited B.S. degree, in exchange for more flexibility in course selection. This program is appropriate for students who have interest in continuing either in the engineering profession or in other postgraduate options such as graduate or professional school.
3. The B.A. in Engineering Sciences (Electrical) requires substantially fewer engineering courses. It is suitable for careers outside technology in which a student nevertheless benefits from an appreciation of electrical engineering perspectives, and it is appropriate as a second major.
4. The fourth major is a joint Electrical Engineering and Computer Science B.S. degree, and has a unique blend of electrical engineering and computer science that retains the rigor of both fields. This degree is a popular choice for those interested in information technology careers.

First-year students interested in the Electrical Engineering major typically take EENG 200 and EENG 201, both excellent introductions to the major. In the sophomore year students take EENG 202 and EENG 203. However, EENG 200 and EENG 201 need not be taken in the first year since these courses are designed such that EENG 200 and EENG 202 can be taken concurrently; as can EENG 201 and EENG 203.

It is difficult to enter the major if students do not take mathematics and physical science prerequisites during the first year. Students without high school calculus should take MATH 112 and MATH 115. First-year students with high school calculus typically take MATH 120 or ENAS 151. Potential majors are also encouraged to take PHYS 180 and PHYS 181, or PHYS 200 and PHYS 201, during the first year.

The director of undergraduate studies (DUS) of Electrical Engineering welcomes consultation with students about their program opportunities at any time. For more details, see the department website.

FACULTY OF THE DEPARTMENT OF ELECTRICAL ENGINEERING

Professors Hui Cao[†], James Duncan[†], Jung Han, Roman Kuc, Tso-Ping Ma, Rajit Manohar, A. Stephen Morse, Kumpati Narendra, Daniel Prober[†], Mark Reed, Peter Schultheiss (*Emeritus*), Lawrence Staib[†], Hemant Tagare[†], Hongxing Tang, Leandros Tassiulas, J. Rimantas Vaišnys, Y. Richard Yang[†]

Associate Professors Richard Lethin (*Adjunct, Lecturer*), Jakub Szefer, Sekhar Tatikonda[†], Fengnian Xia

Assistant Professors Wenjun Hu, Amin Karbasi, Priyadarshini Panda

[†]A joint appointment with primary affiliation in another department.

View Courses

Courses

EENG 101b, The Digital Information Age Priya Panda

An introduction to machine learning for communicating between humans and digital systems. Each student generates data by speaking the ten English digits 0 through 9 into the microphone of a laptop. Programs written in the popular engineering programming language Matlab convert the microphone speech into numerical features that are then processed to have the computer classify the speech sounds into their digit values. The course covers the ideas of template matching and neural networks for digit speech classification. The initial programs are written by the instructor and students modify them with the help of the instructor to accomplish a student-selected task. Intended for students in the humanities and social sciences interested in machine learning and for first-year students considering a major in electrical engineering. A familiarity with any programming language and matrix algebra is helpful. Priority given to non-science majors and first-year students interested in electrical engineering. QR

EENG 200a, Introduction to Electronics Mark Reed

Introduction to the basic principles of analog and digital electronics. Analysis, design, and synthesis of electronic circuits and systems. Topics include current and voltage laws that govern electronic circuit behavior, node and loop methods for solving circuit problems, DC and AC circuit elements, frequency response, nonlinear circuits, semiconductor devices, and small-signal amplifiers. A lab session approximately every other week. After or concurrently with MATH 115 or equivalent. QR, WR, SC

EENG 201b, Introduction to Computer Engineering Priya Panda

Introduction to the theoretical principles underlying the design and programming of simple processors that can perform algorithmic computational tasks. Topics include data representation in digital form, combinational logic design and Boolean algebra, sequential logic design and finite state machines, and basic computer architecture principles. Hands-on laboratory involving the active design, construction, and programming of a simple processor. QR

EENG 202a, Communications, Computation, and Control Wenjun Hu

Introduction to systems that sense, process, control, and communicate. Topics include information theory and coding (compression, channel coding); network systems (network architecture, routing, wireless networks); signals and systems (linear systems, Fourier techniques, bandlimited sampling); estimation and learning (hypothesis testing, regression, classification); and end-to-end application examples (security, communication systems). MATLAB programming assignments illustrate concepts. Students should have basic familiarity with counting (combinatorics), probability and statistics (independence between events, conditional probability, expectation of random variables, uniform distribution). Prerequisite: MATH 115. AP Stats preferred. QR

EENG 203b, Circuits and Systems Design Hongxing Tang

Introduction to design in a laboratory setting. A wide variety of practical systems are designed and implemented to exemplify the basic principles of systems theory. Systems include audio filters and equalizers, electrical and electromechanical feedback systems, radio transmitters and receivers, and circuits for sampling and reconstructing music. Prerequisites: EENG 200 QR, SC RP

*** EENG 235a and EENG 236b, Special Projects** Mark Reed

Faculty-supervised individual or small-group projects with emphasis on laboratory experience, engineering design, or tutorial study. Students are expected to consult the director of undergraduate studies and appropriate faculty members about ideas and suggestions for suitable topics during the term preceding enrollment. These courses may be taken at any time during the student's career. Enrollment requires permission of both the instructor and the director of undergraduate studies, and submission to the latter of a one- to two-page prospectus signed by the instructor. The prospectus is due in the departmental office one day prior to the date that the student's course schedule is due. ½ Course cr per term

EENG 310b, Signals and Systems A Stephen Morse

Concepts for the analysis of continuous and discrete-time signals including time series. Techniques for modeling continuous and discrete-time linear dynamical systems including linear recursions, difference equations, and shift sequences. Topics include continuous and discrete Fourier analysis, Laplace and Z transforms, convolution, sampling, data smoothing, and filtering. Prerequisite: MATH 115. Recommended preparation: EENG 202. QR

EENG 320a / APHY 320a, Introduction to Semiconductor Devices Hongxing Tang

An introduction to the physics of semiconductors and semiconductor devices. Topics include crystal structure; energy bands in solids; charge carriers with their statistics and dynamics; junctions, p-n diodes, and LEDs; bipolar and field-effect transistors; and device

fabrication. Additional lab one afternoon per week. Prepares for EENG 325 and 401. Recommended preparation: EENG 200. PHYS 180 and 181 or permission of instructor QR, SC

EENG 325a, Electronic Circuits Fengnian Xia

Models for active devices; single-ended and differential amplifiers; current sources and active loads; operational amplifiers; feedback; design of analog circuits for particular functions and specifications, in actual applications wherever possible, using design-oriented methods. Includes a team-oriented design project for real-world applications, such as a high-power stereo amplifier design. Electronics Workbench is used as a tool in computer-aided design. Additional lab one afternoon per week. Prerequisite: EENG 200. QR RP

EENG 348b / CPSC 338b, Digital Systems Rajit Manohar

Development of engineering skills through the design and analysis of digital logic components and circuits. Introduction to gate-level circuit design, beginning with single gates and building up to complex systems. Hands-on experience with circuit design using computer-aided design tools and microcontroller programming. Recommended preparation: EENG 201. QR

EENG 397a / ENAS 397a, Mathematical Methods in Engineering J Rimas Vaisnys

Exploration of several areas of mathematics useful in science and engineering; recent approaches to problem solving made possible by developments in computer software. Mathematica and Eureka are used to investigate and solve problems involving nonlinear differential equations, complex functions, and partial differential equations. Prerequisites: MATH 222, and ENAS 194 or MATH 246, or equivalents; familiarity with computer programming. QR

EENG 400b, Electronic Materials Jung Han

Survey and review of fundamental material issues pertinent to modern microelectronic and optoelectronic technology. Topics include band theory, electronic transport, surface kinetics, diffusion, defects in crystals, thin film elasticity, crystal growth, and heteroepitaxy. Formerly EENG 408. Prerequisite: EENG 320 or permission of instructor. QR, SC

EENG 401a, Photonics and Optical Electronics Jung Han

A survey of the enabling components and devices that constitute modern optical communication systems. Focus on the physics and principles of each functional unit, its current technological status, design issues relevant to overall performance, and future directions. Formerly EENG 410. EENG 320 and APHY 322, or permission of instructor QR, SC

EENG 402b / APHY 418b, Advanced Electron Devices Mark Reed

The science and technology of semiconductor electron devices. Topics include compound semiconductor material properties and growth techniques; heterojunction, quantum well and superlattice devices; quantum transport; graphene and other 2D material systems. Formerly EENG 418. Prerequisite: EENG 320 or equivalent. QR, SC

EENG 403b / APHY 321b, Semiconductor Silicon Devices and Technology Tso-Ping Ma

Introduction to integrated circuit technology, theory of semiconductor devices, and principles of device design and fabrication. Laboratory involves the fabrication and analysis of semiconductor devices, including Ohmic contacts, Schottky diodes, p-n junctions, solar cells, MOS capacitors, MOSFETs, and integrated circuits. Formerly EENG 401. Prerequisite: EENG 320 or equivalent or permission of instructor. QR, SC

*** EENG 408a, Emerging CMOS Technology and Beyond** Tso-Ping Ma

This is a "seminar" style course that introduces to students various contemporary topics in emerging CMOS science and technology. Possible topics include Post-Moore's law alternatives, artificial intelligence, neuromorphic computing, quantum computers, emerging memories, and other topics of interest to students. In addition to the instructor, students hear from and interact with world's renowned guest lecturers during and after the regular class hours. Prerequisite: EENG 320 or equivalent, or permission by instructor.

*** EENG 425a, Introduction to VLSI System Design** Richard Lethin

Chip design; integrated devices, circuits, and digital subsystems needed for design and implementation of silicon logic chips. CMOS fabrication overview, complementary logic circuits, design methodology, computer-aided design techniques, timing, and area estimation. Exploration of recent and future chip technologies. A course project is the design, through layout, of a digital CMOS subsystem chip; selected projects are fabricated for students. Prerequisite: familiarity with computer programming and with circuits at the level of introductory physics. QR

EENG 431a, Foundations of Data Science Amin Karbasi

Recent advances in data science have enabled us to make tremendous progress in various fields including robotics, machine learning, computer vision, medicine, etc. This course provides an easy, yet rigorous, introduction to the mathematical and algorithmic foundations of data science. We cover key ideas that have led to such progress from statistics to optimization. The course is organized around three themes: What is learning? What algorithms we can use to learn? How can we optimize resources for efficient learning? Prerequisites: MATH 120, MATH 222, CPSC 365, and STAT 241. SC

*** EENG 432a / AMTH 342a, Linear Systems** A Stephen Morse

Introduction to finite-dimensional, continuous, and discrete-time linear dynamical systems. Exploration of the basic properties and mathematical structure of the linear systems used for modeling dynamical processes in robotics, signal and image processing, economics, statistics, environmental and biomedical engineering, and control theory. Prerequisite: MATH 222 or permission of instructor. QR

EENG 434b / MATH 251b / S&DS 351b, Stochastic Processes Joseph Chang

Introduction to the study of random processes including linear prediction and Kalman filtering, Poisson counting process and renewal processes, Markov chains, branching processes, birth-death processes, Markov random fields, martingales, and random walks. Applications chosen from communications, networking, image reconstruction, Bayesian statistics, finance, probabilistic analysis of algorithms, and genetics and evolution. Prerequisite: S&DS 241 or equivalent. QR

*** EENG 438b, Neural Networks for Pattern Recognition, Identification, and Control** Kumpati Narendra

Design of artificial neural networks (ANN) for approximation, pattern recognition, identification, and control. Introduction to the theory of artificial neural networks and linear adaptive control; adaptive identification and control problems in nonlinear dynamical systems. Applications in engineering and biology. Prerequisite: EENG 436 or permission of instructor. QR

EENG 439a, Neural Networks and Learning Systems Priya Panda

Neural networks (NNs) have become all-pervasive giving us self-driving cars, Siri Voice assistants, Alexa, and much more. While deep NNs deliver state-of-the-art accuracy on many artificial intelligence tasks, it comes at the cost of high computational complexity. Accordingly, designing efficient hardware architectures for deep neural networks is an important step towards enabling the wide deployment of NNs, particularly in low-power computing platforms, such as, mobiles, embedded Internet of Things (IoT) and drones. This course aims to provide a thorough overview on deep learning techniques, while highlighting the key trends and advances toward efficient processing of deep learning in hardware systems, considering algorithm-hardware co-design techniques. Prerequisites: MATH 222 or CPSC 202, EENG 201, and knowledge of Python programming.

EENG 445a / BENG 445a, Biomedical Image Processing and Analysis James Duncan and Lawrence Staib

This course is an introduction to biomedical image processing and analysis, covering image processing basics and techniques for image enhancement, feature extraction, compression, segmentation, registration and motion analysis including traditional and machine learning techniques. Student learn the fundamentals behind image processing and analysis methods and algorithms with an emphasis on biomedical applications. Prerequisite: BENG 352 or EENG 310 or permission of instructors. Recommended preparation: familiarity with probability theory.

EENG 450a, Applied Digital Signal Processing J Rimas Vaisnys

An analysis, by computer, of processing requirements. Relevant probability and estimation theories applied to measurements corrupted by noise. Point estimates and system identification from random processes. MATLAB simulations verify the analysis. Prerequisite: EENG 310 or permission of instructor. QR

*** EENG 451b / CPSC 456b, Wireless Technologies and the Internet of Things** Wenjun Hu

Over the last two decades or so, consumer IoT technologies have evolved from individual analogous devices, to connected devices and then interconnected networks of devices, from data collection to data management, from smart devices to intelligent interfaces. Wireless connectivity is an important driver of IoT technologies. This course aims to weave together fundamental theory of wireless communications, its application to IoT, and the design and implementation of wireless network architectures. The concepts are illustrated using examples such as WiFi and LTE/5G. Particular emphasis is placed on the interplay between concepts and their implementation in real systems. The coursework offers a practical experience, built on lab sessions involving WiFi experiments and simple IoT setups, homework involving Matlab-based analysis, and a student-defined course project that can cater to diverse interests. Students can expect to learn background knowledge of some everyday wireless technologies and how to design systems based on the fundamental communications concepts. Given the nature of these invisible signals, students also gain some experience of dealing with uncertainty in experiments and working towards open-ended goals. Depending on the programming background of the students, we may also explore backend system support in the form of edge or cloud computing. Prerequisites: 1) Introductory courses in mathematics, engineering, or computer science covering basics of the following topics: Linux skills, Matlab programming, probability, linear algebra, and Fourier transform; 2) Or by permission of the instructor. Course material will be self-contained as much as possible. The labs and homework assignments require Linux and Matlab skills and simple statistical and matrix analysis (using built-in Matlab functions). There will be a couple of introductory labs to refresh Linux and Matlab skills if needed.

*** EENG 452a, Internet Engineering** Leandros Tassioulas

Introduction to basic Internet protocols and architectures. Topics include packet-switch and multi-access networks, routing, flow control, congestion control, Internet protocols (IP, TCP, BGP), the client-server model, IP addressing and the domain name system, wireless access networks, and mobile communications. Prerequisite: a college-level course in mathematics, engineering, or computer science, or with permission of instructor. QR

EENG 454b / AMTH 364b / S&DS 364b, Information Theory Andrew Barron

Foundations of information theory in communications, statistical inference, statistical mechanics, probability, and algorithmic complexity. Quantities of information and their properties: entropy, conditional entropy, divergence, redundancy, mutual information, channel capacity. Basic theorems of data compression, data summarization, and channel coding. Applications in statistics and finance. After STAT 241. QR

*** EENG 455b, Network Algorithms and Stochastic Optimization** Leandros Tassioulas

This course focuses on resource allocation models as well as associated algorithms and design and optimization methodologies that capture the intricacies of complex networking systems in communications computing as well as transportation, manufacturing, and energy systems. Max-weight scheduling, back-pressure routing, wireless opportunistic scheduling, time-varying topology network

control, and energy-efficient management are sample topics to be considered, in addition to Lyapunov stability and optimization, stochastic ordering, and notions of fairness in network resource consumption. QR

*** EENG 468a and EENG 469b, Advanced Special Projects** Mark Reed

Faculty-supervised individual or small-group projects with emphasis on research (laboratory or theory), engineering design, or tutorial study. Students are expected to consult the director of undergraduate studies and appropriate faculty members about ideas and suggestions for suitable topics during the term preceding enrollment. This course may only be taken once and at any appropriate time during the student's career; it does not fulfill the senior requirement. Enrollment requires permission of both the instructor and the DUS, and submission to the latter of a one- to two-page prospectus approved by the instructor. The prospectus is due to the DUS one day prior to the date that the student's course schedule is due.

*** EENG 471a and EENG 472b, Senior Advanced Special Projects** Mark Reed

Faculty-supervised individual or small-group projects with emphasis on research (laboratory or theory), engineering design, or tutorial study. Students are expected to consult the director of undergraduate studies and appropriate faculty members about ideas and suggestions for suitable topics during the term preceding enrollment. This course is only open to seniors and is one of the courses that fulfills the senior requirement. Enrollment requires permission of both the instructor and the DUS, and submission to the latter of a one- to two-page prospectus approved by the instructor. The prospectus is due to the DUS one day prior to the date that the student's course schedule is due.

EENG 475a / BENG 475a / CPSC 475a, Computational Vision and Biological Perception Steven Zucker

An overview of computational vision with a biological emphasis. Suitable as an introduction to biological perception for computer science and engineering students, as well as an introduction to computational vision for mathematics, psychology, and physiology students.

Prerequisite: CPSC 112 and MATH 120, or with permission of instructor. QR, SC RP

*** EENG 481b, Advanced ABET Projects** Roman Kuc

Study of the process of designing an electrical device that meets performance specifications, including project initiation and management, part specification, teamwork, design evolution according to real-world constraints, testing, ethics, and communication skills. Design project consists of electronic sensor, computer hardware, and signal analysis components developed by multidisciplinary teams.

Prerequisites: EENG 310, 320, 325, and 348. RP