Electrical Engineering

Major

The Department of Electrical Engineering offers B.S., M.S., and Ph.D. degrees in Electrical Engineering. The Electrical Engineering program objectives are to produce graduates able to:

- develop and pursue successful careers in electrical engineering
- apply electrical engineering knowledge and skills to further careers in a broad range of professional occupations
- conduct successful graduate studies and research at major research universities
- demonstrate innovation and creativity and pursue lifelong learning in solving engineering problems
- work effectively in a team environment, communicate well, attain professional growth, and provide leadership in engineering
- exercise professional responsibility and sensitivity to a broad range of social concerns, such as ethical, environmental, economic, regulatory, and global issues

All undergraduates in the College of Engineering must see an advisor at least annually. Visit www.engr.ucr.edu/studentaffairs for details.

The Electrical Engineering B.S. degree at UCR is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; (410) 347-7700. For more details see www.engr.ucr.edu.

Undergraduate Program Focus Areas

The electrical engineering undergraduate program offers the following focus areas:

1. Communications, Signal Processing and Networking: Fundamental and state-of-the-art theory and applications of communications, networking of devices, and related signal processing, involving information sources in the form of audio, video, image and text messages and transmission media of wire, wireless (radio frequency), fiber optics, etc.

2. Computer Engineering: The Electrical Engineering department offers a Computer Engineering program in conjunction with the Computer Science and Engineering department. Example applications are embedded system design, reconfigurable systems, parallel and high-performance computing, microprocessors, nanometer integrated circuit design, and computer-aided design (CAD) techniques. See detailed descriptions in the Computer Engineering Program.

3. Control and Robotics: Theory and design of control of systems and robots. Example applications include control systems in automotive, satellite, aircraft, computer hard drive, robotic manufacturing, autonomous robots, cell phone signal tracking, among others.

4. Intelligent Systems: Theory, design and development of systems capable of intelligent decisions. Example applications include video surveillance systems, medical imaging devices, intelligent transportation systems, and manufacturing automation.

5. Nanotechnology, Advanced Materials and Devices: Synthesis and characterization of advanced materials at nanometer scale, theory, design and fabrication of electronic and optoelectronic devices. Example applications include creation of ultra-fast low-power transistors, efficient solar cells for energy generation, high-density memory for smart phones and mobile services, and tiny devices for medical applications.

6. VLSI Design and Systems: Theory, design and methodologies of very large scale, nanometer integrated circuits. Example applications include microprocessors, analog and mixed signal circuits, RF circuits for cell phones and wireless networks, system-on-chip (SOC), application specific integrated circuits (ASIC).

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University Requirements

See Undergraduate Studies section.

College Requirements

See The Marlan and Rosemary Bourns College of Engineering, Colleges and Programs section.

The Electrical Engineering major uses the following major requirements to satisfy the college’s Natural Sciences and Mathematics breadth requirement.

1. One course in the biological sciences chosen from an approved list
2. CHEM 001A, CHEM 011A
3. MATH 008B or MATH 009A
4. PHYS 040A, PHYS 040B

Major Requirements

1. Lower-division requirements (70 units)
   a) One course in the biological sciences chosen from an approved list
   b) CHEM 001A, CHEM 011A
   c) CS 010, CS 013, CS 061
   d) EE 001A, EE 011A, EE 011B, EE 010
   e) MATH 008B or MATH 009A, MATH 009B, MATH 009C, MATH 010A, MATH 010B, MATH 046
   f) PHYS 040A, PHYS 040B, PHYS 040C
2. Upper-division requirements (81 units)
   a) EE 100A, EE 100B, EE 105, EE 110A, EE 110B, EE 114, EE 115, EE 116, EE 132, EE 141, EE 175A, EE 175B
   b) CS 120A/EE 120A, CS 120B/EE 120B
   c) ENGR 180
   d) Twenty (20) units of technical electives (chosen with the approval of a faculty advisor) from CS 122A, CS 130, CS 143/EE 143, CS 161, CS 168; EE 117, EE 128, EE 132, EE 133, EE 134, EE 135, EE 136, EE 137, EE 138, EE 139, EE 140, EE 144, EE 146, EE 150, EE 151, EE 152, EE 160

The choice of technical electives must ensure that the upper division requirements include at least one coherent sequence of at least three (3) electrical engineering courses to ensure depth in one area of electrical engineering. Example course sequences are available through the Student Affairs Office in the College of Engineering or http://www.engr.ucr.edu/studentaffairs/.

Graduate Program
The Department of Electrical Engineering offers programs leading to M.S. and Ph.D. degrees.

University requirements for the M.S. and Ph.D. degrees in Electrical Engineering are given in the Graduate Studies section of this catalog.

Research focus areas currently include communications, computer vision, control, detection and estimation, distributed systems, electronic materials, error-correcting codes, image processing, information theory, intelligent sensors, intelligent systems, machine learning, modeling and simulation, multimedia, nanotechnologies and nanodevices, navigation, neural networks, pattern recognition, robotics and automation, signal processing, solid-state devices and circuits, system identification, and transportation systems.

Admission All applicants must submit official scores for the GRE General Test. All applicants whose native language is not English and who do not have a degree from an institution where English is the exclusive language of instruction must complete the Test of English as a Foreign Language (TOEFL) with a minimum score of 550 (paper-based), 213 (computer-based), or 80 (Internet-based).

Applicants must meet the general admission requirements of the Riverside Division of the Academic Senate and the UCR Graduate Council as set forth in the UC Riverside Graduate Student Application. In addition, Master's Degree Applicants should have completed a program equivalent to UCR's B.S. in Electrical Engineering or demonstrate the required knowledge and proficiency in the following subjects:
1. Mathematics, including calculus, differential equations, and complex variables
2. Circuits and electronics (equivalent of EE 100)
3. Signals and systems (equivalent of EE 110)
4. Communication and signal processing (equivalent of EE 115, EE 141)
5. Logic design, digital systems, and micro-computers (equivalent of EE 120)
6. Control systems (equivalent of EE 132)
7. At least one major high-level programming language and associated programming techniques (equivalent of CS 010)

Students with background in other scientific fields are encouraged to apply. Applicants lacking minimum undergraduate preparation in the above areas may be admitted but must take the appropriate undergraduate courses. Under special circumstances, students who have not completed all undergraduate requirements may be admitted provided that the deficiencies are corrected within the first year of graduate study. Courses taken for this purpose do not count towards an advanced degree.

Master of Science
The Department of Electrical Engineering offers the M.S. degree in Electrical Engineering.

General university requirements are listed in the Graduate Studies section of this catalog. Students may obtain an M.S. degree in Electrical Engineering through either Plan I (Thesis) or Plan II (Comprehensive Examination). The normative time for a student to complete the M.S. degree under both Plan I or Plan II is six quarters (two years). Students who are admitted with deficiencies may require up to three additional quarters.

Plan I (Thesis) Students must complete 36 units of graduate or upper-division undergraduate work in Electrical Engineering and other approved subject areas. At least 24 of these units must be in graduate-level courses taken at a campus of the UC, including at least 12 units of required graduate courses. The required and approved courses in each area are determined by the graduate program committee. No more than 12 units may be in graduate research (courses numbered 297 or 299). Upper-division undergraduate courses numbered 125 and above can be counted towards the degree requirements.

A thesis on a research topic must be submitted and approved by the faculty. The thesis must demonstrate the student's in-depth knowledge of the chosen research topic. Publishable results are encouraged. The thesis defense is a two-hour examination session open to the public and begins with a brief presentation of the thesis by the candidate, followed by a question-and-answer session.

Plan II (Comprehensive Examination) The same requirements as in Plan I apply, except that students must complete at least 18 quarter units of graduate-level courses taken at a UC campus, and none of these credits can be in courses numbered 297 or 299. A maximum of 6 units can be taken in Directed Studies (290).

Students must take the comprehensive examination. The examination is conducted jointly with the Ph.D. preliminary examination. The examination emphasizes the fundamental knowledge of the study area rather than the specifics covered in individual courses. Candidates must solve at least five problems in at least three different major areas. No more than three problems may be chosen from the student's major area of specialization (i.e., communications and signal processing; control, robotics, and manufacturing; intelligent systems; circuits and devices).

Normative Time to Degree Six quarters (two years)

Doctoral Degree
The Department of Electrical Engineering offers the Ph.D. degree in Electrical Engineering.

Admission An M.S. or equivalent degree in Electrical Engineering or a related field is normally required. Exceptional applicants may be admitted directly without an M.S. degree. Students with backgrounds in other scientific fields are encouraged to apply. Applicants lacking undergraduate preparation in the above areas may be admitted but must take the appropriate undergraduate courses. Under special circumstances, students who have not completed all undergraduate requirements may be admitted, provided that the deficiencies are corrected within the first year of graduate study. Courses taken for this purpose do not count towards an advanced degree.

Course Work There is no strict course or unit requirement for the Ph.D. degree. The faculty recommends that the student take a minimum of 36 quarter units of 100- or 200-level course work (excluding EE 297 or EE 299) while in graduate standing as evidence of preparation for the doctoral qualifying examination. The courses may include graduate course work used for the M.S. degree.

Students must complete a minimum of six quarters (two years) in residence in the UC with a GPA of 3.00 or better. Students must submit a formal study plan before the end of the second quarter of academic residency. Initially, the plan lists the student's entire expected program of course work. After passing the preliminary examination, an amended version of the study plan must be submitted to and approved by the student's doctoral committee.

Students must establish a major subject area. A coherent program of approximately 24 units of graduate course work in the major area is recommended. Students may need to take considerably more than the 24 units to prepare for the Ph.D. research. The balance of the courses should lend support to the major field of study.
while adding breadth to the student's overall program. These courses may consist of Electrical Engineering courses in an area distinctly different from the major area and/or courses from other campus departments.

**Preliminary Examination**
The purpose of the preliminary examination is to screen candidates for continuation in the doctoral program. The examination is administered by the graduate program committee and is combined with the M.S. comprehensive examination. Candidates must solve at least five problems in at least three different major areas. No more than three problems may be chosen from the student's major area of specialization (i.e., communications and signal processing, control, robotics, and manufacturing; intelligent systems; circuits and devices).

Plan II M.S. candidates who took the combined M.S. comprehensive and Ph.D. preliminary examination and successfully passed at the Ph.D. level are given credit for having passed the Ph.D. preliminary examination.

**Dissertation Proposal and Oral Qualifying Examination**
After passing the preliminary examination, doctoral candidates must prepare and submit a dissertation proposal to their qualifying examination committee before the qualifying examination. The format of the proposal is flexible, but the proposal should clearly indicate the proposed problem under study, demonstrate substantial knowledge of the topic and related issues, state the progress made towards a solution, and indicate the work remaining to be done. The new approaches and methods to be used in the research should also be discussed. An extensive bibliography for the problem under study should be attached to the proposal.

The oral qualifying examination focuses on the dissertation problem. It includes considerable depth in the student's area of specialization, as required for a successful completion of the dissertation. The examination is a three-hour session, which begins with the student's presentation of the dissertation topic and is followed with questions and suggestions by the doctoral committee.

A doctoral dissertation should be an original and substantial contribution to knowledge in the student's major field. It must demonstrate the student's ability to carry out a program of independent advanced research and to report the results in accordance with standards observed in recognized scientific journals.

**Examination and Defense**
When the doctoral committee determines that a suitable draft of the dissertation has been presented, a dissertation examination and defense for the student is scheduled. The defense consists of a public seminar followed by questions from the committee members and the audience.

**Language Requirement**
To meet the degree requirements of the Electrical Engineering program, all admitted Ph.D. students whose native language is not English must take ESL classes until they get a “clear pass” on the TAST or SPEAK test.

**Normative Time to Degree**
12 quarters (15 quarters for students without an M.S. in Electrical Engineering)

**Preparation for Careers in Teaching**
All doctoral students are recommended to be employed as teaching assistants for at least three quarters during their graduate career. The department is developing special courses to aid in the learning of effective teaching methods, such as handling discussion/lab sessions and preparing and grading examinations.

Contact the Graduate Student Affairs Assistant at the Department of Electrical Engineering. (951) 827-2484, or visit ee.ucr.edu for information on graduate courses.

**Lower-Division Courses**

**EE 001A. Engineering Circuit Analysis I (3) Lecture, 3 hours.** Prerequisite(s): PHYS 040C, MATH 046 (both may be taken concurrently); concurrent enrollment in EE 011A. Ohm’s law and Kirchhoff’s laws; nodal and loop analysis; analysis of linear circuits; network theorems; transients in RLC circuits. Application of SPICE to circuit analysis.

**EE 001B. Engineering Circuit Analysis II (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): EE 001A and EE 011A. Sinusoidal steady state analysis, polyphase circuits, magnetically coupled networks, frequency characteristics, Laplace and Fourier transforms, Laplace and Fourier analysis. Application of SPICE to complicated circuit analysis.

**EE 002. Electrical and Electronic Circuits (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): PHYS 040C (may be taken concurrently). Intended for non-Electrical Engineering majors for whom knowing the design of electrical and electronic circuits is not crucial but is helpful. Involves direct-circuit calculations with resistors, inductors, and capacitors, followed by steady state sinusoidal analysis. Discusses logic circuits before electronics, which includes diodes, amplifiers, and transistors.

**EE 010. Introduction to Electrical Engineering (2) Laboratory, 3 hours; lecture, 1 hour.** Prerequisite(s): none. Introduces common everyday electrical engineering and technology devices. Aims to enrich students’ appreciation of technology and the application of simple science and engineering concepts in the design and operation of these electrical and electronic devices, and to provide students with an early positive engineering experience and interaction with departmental faculty. Graded Satisfactory (S) or No Credit (NC).

**EE 011A. Engineering Circuit Analysis I Laboratory (1) Laboratory, 3 hours.** Prerequisite(s): EE 001A (may be taken concurrently). Laboratory experiments closely tied to the lecture material of EE 001A: resistive circuits, attenuation and amplification, network theorems and superposition, operational amplifiers, transient response, application of SPICE to circuit analysis.

**Upper-Division Courses**

**EE 100A. Electronic Circuits (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): EE 001B. Electronic systems: linear circuits, operational amplifiers, diodes, nonlinear circuit applications, junction and metal-oxide-semiconductor field-effect transistors, bipolar junction transistors, MOS and bipolar digital circuits. Laboratory experiments are performed in the subject areas and SPICE simulation is used.

**EE 100B. Electronic Circuits (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): EE 100A. Differential and multistage amplifiers, output stages and power amplifiers, frequency response, feedback, analog integrated circuits, filters, tuned amplifiers, and oscillators. Laboratory experiments are performed in the subject areas and SPICE simulation is used.


**EE 110A. Signals and Systems (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): CS 010, EE 001B (may be taken concurrently); MATH 046. Basic signals and systems time-invariant (LTI) systems, Fourier analysis, frequency response, and Laplace transforms for LTI systems. Laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.

**EE 110B. Signals and Systems (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): EE 110A. Fourier analysis for discrete-time signals and systems, filtering, modulation, sampling and interpolation, 2-transforms. Laboratory experiments with signals, transforms, harmonic generation, linear digital filtering, and sampling/aliasing.

**EE 114. Probability, Random Variables, and Random Processes in Electrical Engineering (4) Lecture, 3 hours; discussion, 1 hour.** Prerequisite(s): EE 110A. Covers fundamentals of probability theory, random variables, and random processes with applications to electrical and computer engineering. Includes probability theory, random variables, densities, functions of random variables, expectations and moments, and multivariate distributions. Also addresses random processes, autocorrelation function, spectral analysis of random signals, and linear systems with random inputs.

**EE 115. Introduction to Communication Systems (4) Lecture, 3 hours; laboratory, 3 hours.** Prerequisite(s): EE 110B. Covers spectral density and correlation, modulation theory, amplitude, frequency, phase and analog pulse modulation and demodulation techniques, signal-to-noise ratios, and system performance calculations. Laboratory experiments involve techniques of modulation and demodulation.

**EE 116. Engineering Electromagnetics (4) Lecture, 3 hours; discussion, 1 hour.** Prerequisite(s): EE 001B (may be taken concurrently). Transmission lines, fields and field operators, electrostatic and magnetostatic fields, time-varying fields, electromagnetics, electromagnetic waves, plane waves, guided waves, and applications to engineering problems.
EE 117. Electromagnetics II (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 116. Applications of Maxwell’s equations. Skin effect, boundary-value problems, plane waves in lossy media, transverse EM waves, hollow metal waveguides, cavity resonators, microstrips, propagation in dielectrics and optical fibers, optical fiber applications, radiation, and antennas. Laboratory work involves both software simulations and hardware experiments in basic electromagnetic technology.

EE 120A. Logic Design (5) Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 061 with a grade of "C-" or better. Covers the design of digital systems. Topics include Boolean algebra, combinational and sequential digital systems, and use of arithmetic logic units, carry-lookahead adders, multiplexers, decoders, comparators, multipliers, flip-flops, registers, and simple memories; state-machine design; and basic register-transfer level design. Interdisciplinary laboratories involve use of hardware description languages, synthesis tools, programmable logic, and significant hardware prototyping. Cross-listed with CS 120A.

EE 120B. Introduction to Embedded Systems (5) Lecture, 3 hours; laboratory, 6 hours. Prerequisite(s): CS 120A/EE 120A. Introduction to hardware and software design of computing systems embedded in electronic devices (such as digital cameras or portable video games). Topics include embedded processor programming, custom processor design, standard peripherals, memories, interfacing, and hardware/software tradeoffs. Interdisciplinary laboratory involves use of synthesis tools, programmable logic, and microcontrollers and development of working embedded systems. Cross-listed with CS 120B.

EE 128. Data Acquisition, Instrumentation, and Process Control (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 120A/EE 120A, EE 100B; or consent of instructor. Analog signal transducers, conditioning and processing, step motors, DC servo motors, and other actuators; analog to digital and digital to analog converters; data acquisition systems; microcomputer interfaces to commonly used sensors and actuators; design principles for electronic instruments, real-time process control and instrumentation.

EE 132. Automatic Control (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 105 or ME 103 or equivalent; EE 110A or ENGR 118; or consent of instructor. Covers mathematical modeling of linear systems for time and frequency domain analysis. Topics include transfer function and state variable representations for analyzing stability, controllability, and observability; and closed-loop control design techniques using Bode, Nyquist, and root-locus methods. Laboratories involve both simulation and hardware exercises.

EE 133. Solid-State Electronics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 100A. Presents the fundamentals of solid-state electronics. Topics include electronic band structure, Fermi and quasi-Fermi levels; doping; contacts; junctions; field-effect, bipolar, and metal-oxide-semiconductor (MOS) transistor; and charge-coupled devices. Also reviews device fabrication concepts.

EE 134. Digital Integrated Circuit Layout and Design (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 120A/EE 120A, EE 001A, EE 001B, EE 100A, EE 100B, EE 133. Covers integrated circuit design, layout, and verification of complementary metal oxide semiconductor (CMOS) with use of computer-aided design tools. Topics covered are digital models, inverters, static logic gates, transmission gates, flip-flops, dynamic logic gates, memory circuits, and digital phase-locked loops.

EE 135. Analog Integrated Circuit Layout and Design (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 001A, EE 001B, EE 100A, EE 100B, EE 133, EE 134. Covers analog circuit design, layout, and verification of complementary metal oxide semiconductor (CMOS) with use of computer-aided design tools. Topics covered are analog metal oxide semiconductor field effect transistor (MOSFET) models, current sources, references, amplified design, nonlinear analog circuits, analog-to-digital converters (ADCs), and digital-to-analog converters (DACs).

EE 136. Semiconductor Device Processing (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 133 or equivalent. Presents device simulations and hands-on experience in integrated-circuit fabrication techniques and device characterization. Using four-mask metal-oxide semiconductor (MOS) technology, students fabricate resistors, junctions, capacitors, and MOS transistors and perform electrical evaluation.

EE 137. Introduction to Semiconductor Optoelectronic Devices (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 133. An introduction to semiconductor optoelectronic devices for optoelectronic communications and signal processing. Topics include basic optical processes in semiconductors, semiconductor light-emitting diode, semiconductor heterojunction lasers, photodetectors, solar cells, optoelectronic modulation, and switching devices.

EE 138. Electrical Properties of Materials (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): upper-division standing; PHYS 040C or equivalent. Introduces the electrical properties of materials. Includes the electron as a particle and a wave; hydrogen atom and the periodic table; chemical bonds; free-electron theory of metals; band theory of solids; semiconductors and dielectrics; measurements of material properties; and growth and preparation of semiconductors.

EE 139. Magnetic Materials (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): upper-division standing; PHYS 040C or equivalent. Introduces fundamentals of magnetic materials for the next-generation magnetic, nanomagnetic, and spintronics-related technologies. Includes basic principles of magnetism, models of the equivalent magnetic charge and current, paramagnetic and diamagnetic materials, soft and hard magnetic materials, equivalent magnetic circuits, and magnetic system design foundations.

EE 140. Computer Visualization (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): senior standing in Computer Engineering, Computer Science, or Electrical Engineering. Introduction to visual perception and thinking, fundamentals of three-dimensional geometrical transformations, camera models, perspective transformation, illumination and color models, ray tracing, representations of three-dimensional shape, texture, motion and shading, and rendering and animation. Laboratories on visual realism methods cover three-dimensional modeling, viewing, and rendering.

EE 141. Digital Signal Processing (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B. Transform analysis of Linear-Time-Invariant (LTI) systems, discrete Fourier Transform (DFT) and its computation, Fourier analysis of signals using the DFT, filter design techniques, structures for discrete-time systems. Laboratory experiments on DFT, fast Fourier transforms (FFT), infinite impulse response (IIR), and finite impulse response (FIR) filter design, and quantization effects.

EE 143. Multimedia Technologies and Programming (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): CS 010 or knowledge of an object-oriented or fourth-generation (scripting) programming language, for example, C++, Hypertalk, Supertalk, Lingo, OpenScript, ScriptIt. Introduces multimedia technologies and programming techniques, multimedia hardware devices, authoring languages and environments, temporal and nontemporal media (interactivity in text, graphics, audio, video, and animation), applications, and trends. A term project is required. Cross-listed with CS 143.

EE 144. Introduction to Robotics (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 132. Basic robot components from encoders to microprocessors. Kinematic and dynamic analysis of manipulators. Open-and-closed-loop control strategies, task planning, contact and noncontact sensors, robotic image understanding, and robotic programming languages. Experiments and projects include robot arm programming, robot vision, and mobile robots.

EE 146. Computer Vision (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): senior standing in Computer Science, Computer Engineering, or consent of instructor. Imaging formation, early vision processing, boundary detection, region growing, two-dimensional and three-dimensional object representation and recognition techniques. Experiments for each topic are carried out.

EE 150. Digital Communications (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 114, EE 115. Topics include modulation, probability and random variables, correlation and power spectra, information theory, errors of transmission, equalization and coding methods, shift and phase keying, and a comparison of digital communication systems.

EE 151. Introduction to Digital Control (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 132, EE 141. Review of continuous-time control systems; review of Z-transform and properties; sampled-data systems; stability analysis and criteria; frequency domain analysis and design; transient and steady-state response; state-space methods; controllability and observability; pole placement; observer design; Lyapunov stability analysis. Laboratory experiments complementary to these topics include simulations and hardware design.

EE 152. Image Processing (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 110B. Digital image acquisition, image enhancement and restoration, image compression, computer implementation and testing of image processing techniques. Students gain hands-on experience of complete image processing systems, including image acquisition, processing, and display through laboratory experiments.

EE 160. Fiber-Optic Communication Systems (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 111, EE 116. An introduction to fiber-optic communication systems. Topics include optical fiber transmission, optical amplifiers, transmitters, receivers, and wavelength-division multiplexing.

EE 162. Introduction to Nanoelectronics (4) Lecture, 3 hours; term paper, 3 hours. Prerequisite(s): EE 133 or consent of instructor; familiarity with MATLAB or equivalent and with basic matrix algebra is recommended. Presents the basic concepts of nanoelectronics with a focus on current flow through nanostructured devices. Topics include new paradigms of nanoelectronics, an atomistic view of electrical resistance, Schroedinger’s equation, Coulomb blockade, basis functions, bandstructure, quantum capacitance, level broadening, and coherent transport.
EE 175A. Senior Design Project (4) Consultation, 1 hour; lecture, 1 hour; laboratory, 6 hours. Prerequisite(s): ENGR 180, senior standing in Electrical Engineering. Under the direction of a faculty member, students individually or in small teams with shared responsibilities) propose and design electrical engineering devices or systems. Requires detailed oral report of project and plan test. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment. Graded In Progress (IP) until EE 175A and EE 175B are completed, at which time a final, letter grade is assigned.

EE 175B. Senior Design Project (4) Consultation, 1 hour; lecture, 1 hour; laboratory, 6 hours. Prerequisite(s): EE 175A, senior standing in Electrical Engineering. Under the direction of a faculty member, students (individually or in small teams with shared responsibilities) build, test, and redesign electrical engineering devices or systems. Requires a written report and an oral presentation of the design aspects. Satisfactory (S) or No Credit (NC) grading is not available.

EE 190. Special Studies (1-5) Individual study, 3-15 hours. Prerequisite(s): consent of instructor and department chair. Individual study to meet special curricular needs. Course is repeatable to a maximum of 9 units.

EE 191 (E-2). Seminar in Electrical Engineering (1-4) Seminar, 2-8 hours. Prerequisite(s): upper-division standing or consent of instructor. Additional prerequisites may be required for some segments of this course, see department. Consideration of current topcis in electrical engineering. Offered in summer only.

EE 194. Independent Reading (1-2) Extra reading, 3-6 hours. Prerequisite(s): upper-division standing or consent of instructor. Independent reading in material not covered in course work. Normally taken in senior year. Course is repeatable to a maximum of 4 units.

EE 197. Research for Undergraduates (1-4) Outside research, 3-12 hours. Prerequisite(s): consent of instructor and Electrical Engineering undergraduate program advisor. Directed research on a topic relevant to electrical engineering. Requires a final written report. Course is repeatable to a maximum of 8 units.

EE 198-I. Individual Internship in Electrical Engineering (1-12) Internship, 2-24 hours; written work, 1-12 hours. Prerequisite(s): upper-division standing; at least 12 units in Electrical Engineering. Provides the undergraduate student with career experience as an electrical engineer in an industry or a research unit under the joint supervision of an off-campus sponsor and a faculty member in Electrical Engineering. Each individual program must have the prior approval of both supervisors. Requires a written report. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 12 units.

Graduate Courses

EE 201. Applied Quantum Mechanics (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): MATH 046, PHYS 040A; or consent of instructor. Covers topics in quantum mechanics including Schrödinger equation, operator formalism, harmonic oscillator, quantum wells, spin, bosons and fermions, solids, perturbation theory, Wentzel-Kramers-Brillouin approximation, tunneling, tight-binding model, quantum measurements, quantum cryptography, and quantum computing.

EE 202. Fundamentals of Semiconductors and Nanostructures (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 133, EE 201; or consent of instructor. Examines principles of semiconductor materials and nanostructures. Topics include periodic structures, electron and phonon transport, defects, optical properties, and radiative recombination. Also covers absorption and emission of radiation in nanostructures, and nonlinear optics effects. Emphasizes properties of semiconductor superlattices, quantum wells, wires, and dots.

EE 203. Solid-State Devices (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 133 or consent of instructor. Covers electronic devices including p/n-junctions, fieldeffect transistors, heterojunction bipolar transistors, and nanostructure devices. Explores electrical and optical properties of semiconductor heterostructures, superlattices, quantum wires and dots, as well as devices based on these structures.

EE 204. Advanced Electromagnetics (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 117 or consent of instructor. Presents selected topics in electromagnetic theory and antenna design. Topics include power transmission and attenuation in microstrip transmission lines (TL) and waveguides (WG); transient analysis and applications of TL and WG; radiation of electromagnetic waves; antenna design; electromagnetic interference and compatibilit;y and numerical methods in electromagnetic theory.

EE 205. Optoelectronics and Photonic Devices (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 203, 204, or consent of instructor. A study of the physical optical and photonic devices and their use in an optical communication system. Covers silica fibers, light-emitting diodes (LEDs), heterojunction lasers, p-i-n photodiodes, and avalanche photodiodes.

EE 206. Nanoscale Characterization Techniques (4) Lecture, 3 hours; laboratory, 3 hours. Prerequisite(s): EE 201, EE 202; EE 203, or consent of instructor. An in-depth study of nanoscale materials and device characterization methods. Includes atomic force microscopy (AFM) and scanning tunneling microscopy (STM). Topics include semiconductor fabrication fundamentals; metrology requirements; in situ monitoring; interconnected and failure analysis; principles of AFM, STM, and scanning electron microscopy. X-ray methods; optical and infrared techniques; and electrical characterization.

EE 207. Noise in Electronic Devices (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 203 or consent of instructor. A study of fluctuations processes in solids and noise in electronic devices. Topics include the theory of random processes and analysis of noise types such as generation-recombination noise, low-frequency noise, random telegraph noise, thermal noise, and short noise.

EE 208. Semiconductor Electron, Phonon, and Optical Properties (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 202. Topics include semiconductor electronic band structure theory and methods; phonon dispersion theory and methods; defects in semiconductors; and optical properties of semiconductors. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

EE 209. Semiconductors and Quantum Mechanics (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 201, EE 203, EE 208. Covers the Boltzmann transport equation as applied to semiconductor device modeling. Topics include the physics of carrier scattering in common semiconductors, theoretical treatments of low and high field transport, balance equations, and Monte Carlo solutions. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

EE 210. Advanced Digital Signal Processing (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 110B, EE 141. Provides in-depth coverage of advanced techniques for digital filter and power spectral estimation. Topics include digital filter design, discrete random signals, finite-wordlength effects, non-parametric and parametric power spectrum estimation, multirate digital signal processing, least square methods of digital filter design, and digital filter applications.

EE 211. Adaptive Signal Processing (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 210, EE 215, EE 236. Provides an in-depth understanding of adaptive signal processing techniques. Covers Wold decomposition, Yule-Walker equations, spectrum estimation, Weiner filters, linear prediction, Kalman filtering, time-varying system tracking, nonlinear adaptive filtering, and performance analysis of adaptive algorithms and their variations including stochastic gradient, least mean square, least squares, and recursive least squares.

EE 212. Quantum Electron Transport (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 208. Covers the theory and methods used to model quantum electron transport in ultrascalar traditional semiconductor devices such as transistors, nanoscaled research semiconductor devices (such as quantum dots), and novel electronic material systems (such as carbon nanotubes and molecular wires.) May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

EE 213. Computer-Aided Electronic Circuit Simulation (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 001A, EE 001B, EE 133. Introduction to numerical algorithms and computer-aided techniques for the simulation of electronic circuits. Covers theoretical and practical aspects of important analyses. Topics include circuit formulation methods, large-signal noise models, small-signal alternating current, and moment-matching tran-sient; sensitivity; and noise. Also discusses recent advances in timing analysis, symbolic analysis, and radio frequency circuit analysis.

EE 214. Single-Electronics and Quantum Computing (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 201 or equivalent; graduate standing or consent of instructor. Introduces single-electron devices and their potential use in very large-scale integration applications and quantum computers. Topics include Coulomb blockade, “orthodox” theory of single-electron tunneling, single-electron transistor, shot noise theory superconducting and quantum dot single-electron devices, analog applications, single-electron memory and logic, basic principles of quantum computing and quantum cryptography. Shor’s algorithm, quantum error correction, and potential solid-state realizations of a quantum computer.

EE 215. Stochastic Processes (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): study of probability theory and stochastic processes, with a focus on the most fundamental aspects of modern communication, control, and signal processing systems driven by random signal inputs. Topics include random variables and stochastic processes, spectral analysis, Wiener optimum filter, matched filter, and Karhunen-Loève expansion; mean square estimation theory including smoothing, filtering, and linear prediction; Levinson’s.
algorithm, lattice filters, and Kalman filters; and the Markov process.

EE 216. Nanoscale Phonon Engineering (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 202. Studies acoustic and optical phonons that affect electrical, thermal, and optical properties of materials. Focusses on the confinement-induced changes of phonon properties in nanostructures and their implications for performance of electronic, thermoelectric, and optoelectronic devices. Explores phonon theory, Raman spectroscopy and other phonon characterization techniques, thermal conductivity, and related measurements.

EE 219. Advanced Complementary Metal Oxide Semiconductor (CMOS) Technology (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 203. Introduces advanced complementary metal oxide semiconductor (CMOS) technology. Topics include MOS field effect transistor (MOSFET) scaling, short and narrow channel effects, high field effects, vertical MOSFET transistors, single electron transistors, MOSFET nonvolatile memory devices, and small- and large-signal MOSFET models. Covers CMOS process integration.

EE 220. Applied Ferromagnetism (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 116; consent of instructor. Introduces fundamentals of ferromagnetism necessary to develop next-generation nanomagnetic and spintronics-related devices. Includes basics of magnetism, magnetic circuits, ferromagnetic resonance (FMR), nuclear magnetic resonance (NMR), spintronics, and analyses of applications.

EE 223. Numerical Analysis of Electromagnetic Devices (4) Lecture, 4 hours. Prerequisite(s): EE 117, MATH 151C. Covers in depth the numerical and mathematical foundations of the contemporary computer modeling techniques used in the design and analysis of electromagnetic devices and systems. Provides hands-on experience in modeling systems such as radio frequency devices, magnetic systems, and electromagnetic motors.

EE 224. Digital Communication Theory and Systems (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 115; either the MATH 149A and MATH 149B sequences, the STAT 160A and STAT 160B sequence, or equivalents. Provides an overview of basic communication techniques and an introduction to optimum signal detection and correction. Topics include sampling and bandwidth; pulse code modulation; line coding and pulse shaping; delta modulation; stochastic approach to bandwidth and noise corruption; white Gaussian noise; matched filter; optimum signal detection; Shannon theorem; and error correction.

EE 225. Error-Correcting Codes (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 215 or consent of instructor. Provides an overview of basic error-correcting techniques used in data transmission and storage. Topics include groups and Galois fields, error correction capability and code design of Hamming codes, cyclic codes, Bose-Chaudhuri-Hocquengem (BCH) codes, and Reed-Solomon codes. Also considers concatenated design and decoding techniques.

EE 226. Wireless Communications (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 215, EE 224. Presentation of fundamental cellular concepts and new techniques in wireless communications. Topics include cellular systems and standards, frequency reuse, system capacity, channel allocation, cellular radio propagation, fading channel modeling and equalization, spread spectrum communications and other multiple access techniques, and wireless networking.

EE 227. Spread Spectrum Communications (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 115, EE 215; or consent of instructor. Provides an overview of spread spectrum communication techniques. Topics include direct sequence, frequency hopping and hybrid spread spectrum, pseudorandom sequence generation, modulation and spreading, code tracking, carrier synchronization, coherent and noncoherent data demodulation over fading channels, direct sequence multiple access, and performance evaluation of various multiuser detectors. Xu

EE 228. Fundamentals of Data Compression (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 215 (may be taken concurrently). Covers the fundamental theory and tools for designing data and signal compression systems. Topics include lossless coding, scalar quantization, predictive and transform coding techniques, vector quantization, and the general trade-off between the reproduction signal quality and the bit-rate of the digital representation. Provides a foundation for further study and research in speech, audio, image, and video compression.

EE 229. Video Processing and Communication (4) Lecture, 3 hours; laboratory, 1 hour; extra reading, 2 hours. Prerequisite(s): EE 150, EE 210. Covers the fundamental principles and technologies in the compression and transmission of coded video streams over wired and wireless networks, including wireless network protocols, compression standards, digital signal processor architectures, network or traffic management; quality of service, rate control schemes, and error resilience.

EE 230. Linear System Theory (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 132, MATH 113. Provides a review of linear algebra. Topics include the mathematical description of linear systems; the solution of state-space equations; controllability and observability; canonical and minimal realization; and state feedback, pole placement, observer design, and compensator design.

EE 230. State and Parameter Estimation Theory (4) Lecture, 3 hours; discussion, 1 hour. Prerequisite(s): EE 132. Introduces the theory of stochastic optimal control systems, including Q-parameterization and all stabilizing controllers; frequency domain analysis of uncertain systems; the minimum principle; the Hamilton-Jacobi-Bellman equation; and the algebraic Ricatti equation.

EE 240. Pattern Recognition (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 144 or consent of instructor. Covers basics of pattern recognition techniques. Topics include hypothesis testing, parametric classifiers, parameter estimation, nonparametric density estimation, nonparametric classifiers, feature selection, discriminant analysis, and clustering.

EE 241. Advanced Digital Image Processing (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 152 or consent of instructor. Covers advanced topics in digital image processing. Examines image sampling and quantization, image transforms, stochastic image models, image filtering and restoration, and image data compression.

EE 242. Intelligent Systems (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 146 or consent of instructor. A study of three-dimensional computer vision. Topics include projective geometry, modeling and calibrating cameras, representing geometric primitives and their uncertainty, stereo vision, motion analysis and tracking, interpolating and approximating three-dimensional data, and recognition of two-dimensional and three-dimensional objects.

EE 244. Computational Learning (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): graduate standing or consent of instructor. Explores fundamental concepts of design of intelligent systems. Topics include biological versus computational system, knowledge representation, computational reasoning, computational learning, language and human-machine communication, expert systems, computational vision, and examples of intelligent machines.

EE 245. Advanced Computer Vision (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 144, EE 235. Topics include robotics, mechatronics, and automation systems; design and analysis; mechanics; sensing and programming; linear and non-linear control; rigid and flexible systems; redundant robots; perception-driven action; multibeam cooperation; distributed autonomous robotic systems; programming languages and tools; simulations techniques; and application to mechatronics, manufacturing, and biomorphic systems.

EE 246. Intelligent Transportation Systems (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): graduate standing or consent of instructor. EE 115 and EE 132 are recommended. Focuses on the control, communications, and computer aspects of intelligent transportation systems. Topics include traffic flow theory fundamentals, intelligent transportation system user services, travel and traffic management, advanced vehicle safety systems, intelligent transportation system applications, architectures, standards, strategic needs assessment and deployment, and evaluation.
Course is repeatable to a maximum of 12 units.

EE 247. Current Topics in Computer Vision and Pattern Recognition (4) Lecture, 3 hours; outside research, 3 hours. Prerequisite(s): EE 240 or EE 243 or consent of instructor. Explores advanced mathematical techniques of recent research interest. Topics include particle filters, sampling techniques, stochastic optimization, stochastic approximation algorithms, independent components analysis, energy function techniques, nonlinear discriminant analysis, and support vector machines.

EE 250. Information Theory (4) Lecture, 3 hours; extra reading, 3 hours. Prerequisite(s): EE 215. An overview of fundamental limitations imposed on communication systems. Topics include Shannon's information measures, weak and strong typicality, lossless data compression, source and channel models and Shannon's coding theorems, channel capacity and the rate-distortion function, Gaussian sources and channels, and limits of communication between multiple terminals.

EE 251. Algorithmic and Combinatorial Coding Theory (4) Seminar, 2 hours; lecture, 2 hours. Prerequisite(s): EE 225 or consent of instructor. Explores combinatorial and algorithmic techniques in coding theory. Covers algebraic design of Bose-Chaudhuri-Hocquenghem (BCH) codes and Reed-Muller codes. Algorithmic topics include gradient-like decoding, split syndromes techniques, and information-set decoding. Introduces decoding with polynomial complexity based on Bayesian estimation, iterative decoding, and codes on graphs. May be taken Satisfactory (S) or No Credit (NC) with consent of instructor and graduate advisor.

EE 259. Colloquium in Electrical Engineering (1) Colloquium, 1 hour. Prerequisite(s): graduate standing. Lectures on current research topics in electrical engineering presented by faculty members and visiting scientists. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

EE 260. Seminar in Electrical Engineering (4) Seminar, 4 hours. Prerequisite(s): consent of instructor. Seminar on current research topics in electrical engineering, including areas such as signal processing, image processing, robots, intelligent systems, computer vision, and pattern recognition. Course is repeatable to a maximum of 16 units.

EE 290. Directed Studies (1-6) Individual study, 3-18 hours. Prerequisite(s): graduate standing; consent of instructor and Graduate Advisor. Individual study, directed by a faculty member, of selected topics in electrical engineering. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 12 units.

EE 297. Directed Research (1-6) Outside research, 3-18 hours. Prerequisite(s): graduate standing; consent of instructor. Research conducted under the supervision of a faculty member on selected problems in electrical engineering. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

EE 298-I. Individual Internship in Electrical Engineering (1-12) Internship, 2-24 hours; written work, 1-12 hours. Prerequisite(s): graduate standing; consent of instructor. Provides the Electrical Engineering graduate student with career experience as an electrical engineer in an industry or a research unit. Includes fieldwork with an approved professional individual or organization and academic work under the direction of a faculty member. Requires a final report. Graded Satisfactory (S) or No Credit (NC). Course is repeatable to a maximum of 12 units.

EE 299. Research for the Thesis or Dissertation (1-12) Outside research, 3-36 hours. Prerequisite(s): graduate standing; consent of instructor. Research in electrical engineering for the M.S. thesis or Ph.D. dissertation. Graded Satisfactory (S) or No Credit (NC). Course is repeatable.

### Engineering

**Subject abbreviation:** ENGR

**The Marian and Rosemary Bouns College of Engineering**

### Lower-Division Courses

**ENGR 001 (E-Z). Professional Development and Mentoring (1) Activity, 30 hours per quarter.**
**Prerequisite(s):** senior standing in the Bourns College of Engineering. Provides seniors with involvement in professional development activities. To be performed are program-specific, and may include projects, industry overviews and interactions, involvement with professional societies and clubs, team building, career guidance, and coverage of ethics and lifelong learning issues. E. Bioengineering; F. Chemical Engineering; G. Computer Engineering; H. Computer Science; J. Electrical Engineering; K. Environmental Engineering; M. Information Systems. Graduated Satisfactory (S) or No Credit (NC). Course is repeatable as topics change.

**ENGR 002 (E-Z). Professional Development and Mentoring (1) Activity, 30 hours per quarter.**
**Prerequisite(s):** junior standing in the Bourns College of Engineering. Provides sophomores with involvement in professional development activities. Activities to be performed are program-specific, and may include projects, industry overviews and interactions, involvement with professional societies and clubs, team building, career guidance, and coverage of ethics and lifelong learning issues. E. Bioengineering; F. Chemical Engineering; G. Computer Engineering; H. Computer Science; J. Electrical Engineering; K. Environmental Engineering; M. Information Systems. Graduated Satisfactory (S) or No Credit (NC). Course is repeatable as topics change.

**ENGR 010. Introduction to Engineering (2) Discussion, 1 hour; laboratory, 3 hours. Prerequisite(s): none.**
Introduction to and experience with common everyday engineering and technology devices. Aims to enrich students' appreciation of technology and the application of simple science and engineering concepts in the design and operation of these devices, and to provide students with an early positive engineering experience and interaction with College of Engineering faculty. Graded Satisfactory (S) or No Credit (NC). Credit is awarded for only one of ENGR 010 or ME 001A.

**ENGR 092. First-Year Seminar in Engineering (1) Seminar, 10-15 hours per quarter. Prerequisite(s):** Freshman standing. Enrollment priority is given to freshmen, but sophomores may enroll on a space-available basis with consent of instructor. Introduction to one of the many areas of study explored by the faculty of the College of Engineering in a small-group, highly interactive format. Graded Satisfactory (S) or No Credit (NC). Course is repeatable as topics change to a maximum of 3 units of any combination of ENGR 092, HASS 092, and NASC 092; students may enroll in only one unit of ENGR 092, HASS 092, or NASC 092 per quarter.

### Upper-Division Courses

**ENGR 101 (E-Z). Professional Development and Mentoring (1) Activity, 30 hours per quarter.**
**Prerequisite(s):** junior standing in the Bourns College of Engineering. Provides juniors with involvement in professional development activities. Activities to be performed are program-specific, and may include projects, industry overviews and interactions, involvement with professional societies and clubs, team building, career guidance, and coverage of ethics and lifelong learning issues. E. Bioengineering; F. Chemical Engineering; G. Computer Engineering; H. Computer Science; J. Electrical Engineering; K. Environmental Engineering; M. Information Systems.

**ENGR 102 (E-Z). Professional Development and Mentoring (1) Activity, 30 hours per quarter.**
**Prerequisite(s):** senior standing in the Bourns College of Engineering. Provides seniors with involvement in professional development activities. Activities to be performed are program-specific, and may include projects, industry overviews and interactions, involvement with professional societies and clubs, team building, career guidance, and coverage of ethics and lifelong learning issues. E. Bioengineering; F. Chemical Engineering; G. Computer Engineering; H. Computer Science; J. Electrical Engineering; K. Environmental Engineering; M. Information Systems.

**ENGR 118. Engineering Modeling and Analysis (5) Lecture, 4 hours; discussion, 1 hour. Prerequisite(s):** CHEM 001A or CHEM 01HA; CS 010; MATH 046; PHYS 040B; or consent of instructor. Covers the formulation of mathematical models for engineering systems; applying mass, momentum, and energy balances to derive governing differential equations; solving equations with the use of spreadsheets and other software packages; and fitting linear and nonlinear models to experimental data. Credit is awarded for only one of ENGR 118 or ME 118.

**ENGR 180. Technical Communications (3) Lecture, 2 hours; workshop, 3 hours. Prerequisite(s):** ENGL 001C or ENGL 01SC; upper-division standing. Develops oral, written, and graphical communication skills. Involves extensive oral communication and presentations in small groups, and preparing and critiquing reports, proposals, instructions, and business correspondence. Emphasizes professional and ethical responsibilities and the need to stay current on technology and its global impact on economics, society, and the environment.

**ENGR 190. Special Studies (1-5) Individual study, 3-15 hours. Prerequisite(s):** upper-division standing or consent of instructor. To be taken with the consent of the chair of the appropriate Engineering program as a means of meeting special curricular requirements. Units in this course may not be used to meet requirements for the major unless so designated as a replacement for a requirement not being offered during the student's remaining tenure. Course is repeatable to a maximum of 9 units.

**ENGR 191S. Seminar in Sacramento (4) Seminar, 3 hours; outside research, 3 hours. Prerequisite(s):** upper-division standing or consent of instructor;