and timely education that includes not only strength in the fundamental principles but also experience with the practical skills that are needed to contribute to the complex technological infrastructure of our society. This approach will enable each of our graduates to continue learning throughout an extended career.

• Research: We will develop relevant and innovative science and technology through our research that addresses the needs of industry, government and the scientific community. This technology can be transferred through our graduates, through industrial affiliations, and through publications and presentations.

We provide a faculty that is committed to education and research, is accessible to students, and is highly qualified in their areas of expertise.

Educational Objectives
The educational objectives of the Electrical Engineering Program identify what we hope that our graduates will accomplish within a few years after graduation.

1. We expect our graduates to make positive contributions to society in fields including, but not limited to, engineering.
2. We expect our graduates to have acquired the ability to be flexible and adaptable, showing that their educational background has given them the foundation needed to remain effective, take on new responsibilities and assume leadership roles.
3. We expect some of our graduates to pursue their formal education further, including graduate study for master’s and doctoral degrees.

Program Outcomes
The EE program expects our students upon graduation to have:

1. Acquired strong basic knowledge and skills in those fundamental areas of mathematics, science, and electrical engineering that are required to support specialized professional training at the advanced level and to provide necessary breadth to the student’s overall program of studies. This provides the basis for lifelong learning.
2. Experienced in-depth training in state-of-the-art specialty areas in electrical engineering. This is implemented through our senior electives. Students are required to take two sequences of at least two courses each at the senior level.
3. Benefited from imaginative and highly supportive laboratory experiences where appropriate throughout the program. The laboratory experience will be closely integrated with coursework and will make use of up-to-date instrumentation and computational facilities. Students should experience both hardware-oriented and simulation-oriented exercises.
4. Experienced design-oriented challenges that exercise and integrate skills and knowledge acquired in several courses. These may include design of compo-

Bachelor of Science—Computer Engineering
This major is offered jointly by the Department of Computer Science and the Department of Electrical and Computer Engineering. For information about this major, see page 25.

Electrical & Computer Engineering Courses
Many of the ECE courses are restricted to ECE majors only. Instructor and quarter offered are subject to change.

LOWER DIVISION
1A. Computer Engineering Seminar
(1) STAFF
Prerequisite: Open to computer engineering majors only. Seminar: 1 hour
Introductory seminar to expose students to a broad range of topics in Computer Engineering.

1B. Ten Puzzling Problems in Computer Engineering
(1) PARHAMI
Prerequisite: Open to pre-computer engineering and computer engineering majors only. Not open for credit for those who have taken ECE 1. Gaining familiarity with, and motivation to study, the field of computer engineering, through puzzle-like problems that represent a range of challenges facing computer engineers in their daily problem-solving efforts and at the frontiers of research.

3. Introduction to Electrical Engineering
(4) STAFF
Prerequisites: Open to EE majors only. Lecture, 3 hours; laboratory, 2 hours
Introduction to fundamental design problems in Electrical Engineering through programming in Python. Includes basics of software engineering, algorithm design, data structures, with design problems derived from signals systems. Specific areas will include 1-D and 2-D signal processing, basic transforms and applications.

5. Introduction to Electrical & Computer Engineering
(4) STAFF
Prerequisite: Open to Electrical Engineering and Computer Engineering majors. Lecture: 2 hours; Laboratory: 3 hours
Aims at exposing freshmen students to the different sub-fields within Electrical and Computer Engineering. Composed of lectures by different faculty members and a weekly laboratory based on projects that are executed using the Arduino environment.

10A. Foundations of Analog and Digital Circuits & Systems
(3) STAFF
Prerequisite: Mathematics 2A-B or 3A-B or Mathematics 3AH-3BHI, and Mathematics 3C or 4A or 4AI with a minimum grade of C, and, Math 4B or 4BI or 5A with a minimum grade of C (may be taken concurrently), Physics 3 or 23 (may be taken concurrently); open only to electrical engineering and computer engineering majors. Lecture: 3 hours Not open for credit for those who have received a C- or higher in ECE 2A.

The objective of the course is to establish the foundations of analog and digital circuits. The course will introduce the student to the power of abstraction, resistive networks, network analysis, nonlinear analysis and the digital abstraction. (F)

10AL. Foundations of Analog and Digital Circuits and Systems Lab
(3) STAFF
Prerequisite: ECE 10A (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours Not open for credit for those who have received a C- or higher in ECE 2A.

The goal of 10AL is to provide the student with
Prerequisite: consent of instructor. Group studies intended for small number of advanced students who share an interest in a topic not included in the regular departmental curriculum.  

96. Undergraduate Research

(2-4 STAFF)

Prerequisite: ECE 10A with a C- or better grade. Lecture: 3 hours

Not open for credit for those who have received a C- or higher in ECE 2B.

The objective of the course is to introduce the MOSFET both as a simple digital switch and as controlled current source for analog design. The course will cover basic digital design, small-signal analysis, charge storage elements and operational amplifiers. (W)

10B. Foundations of Analog and Digital Circuits and Systems Lab

(2 STAFF)

Prerequisite: ECE 10B (may be taken concurrently) with a C- or better grade. Laboratory: 4 hours

Not open for credit for those who have received a C- or higher in ECE 2B.

The goal of 10BL is to provide the student with a hands-on application of the concepts discussed in ECE 10B. The lab will utilize the microcontroller to introduce students to the understanding of datasheets for both digital and analog circuits, single-stage amplifier design and basic instrumentation.

10C. Foundations of Analog and Digital Circuits and Systems

(2 STAFF)

Prerequisite: ECE 10C (may be taken concurrently) with a C- or better grade. Lecture: 3 hours

Not open for credit for those who have received a C- or higher in ECE 2C.

The objective of the course is to introduce the student to the basic transient analysis. The course will cover basic digital design, small-signal analysis, charge storage elements and operational amplifiers. (W)

10CL. Foundations of Analog and Digital Circuits and Systems Lab

(2 STAFF)

Prerequisite: ECE 10CL with a C- or better grade. Laboratory: 4 hours

Not open for credit for those who have received a C- or higher in ECE 2CL.

The goal of the course is to introduce the student to the basic transient analysis. The course will cover basic digital design, small-signal analysis, charge storage elements and operational amplifiers. (W)

15A. Fundamentals of Logic Design

(4) ZHANG

Prerequisites: Open to electrical engineering, computer engineering, and pre-computer engineering majors only.

Not open for credit to students who have completed ECE 15. Lecture, 3 hours; discussion, 1 hour.

Boolean algebra, logic of propositions, minterm and maxterm expansions, Karnaugh maps, Quine-McCluskey methods, multi-level circuits, combinational circuit design and simulation, multiplexers, decoders, programmable logic devices.

92. Projects in Electrical and Computer Engineering

(4) STAFF

Prerequisite: Consent of instructor; for Electrical Engineering and Computer Engineering majors only

Projects in electrical and computer engineering for advanced undergraduate students.

94AA-ZZ. Group Studies in Electrical and Computer Engineering

(1-4 STAFF)
multiplexing components, optical filters, basic transmission system analysis and design.

137A. Circuits and Electronics I

 prerequisites: ECE 10A-B-C and ECE 10AL-BL-CL or ECE 2A-B-C, 130A, and 132 all with a minimum grade of C- in all; open to EE majors only. Lecture, 3 hours; laboratory, 3 hours.

Analysis and design of single stage and multistage transistor circuits including biasing, gain, impedances and maximum signal levels.

137B. Circuits and Electronics II

 prerequisites: ECE 10C or ECE 2C and 137A with a minimum grade of C- in both; open to EE majors only. Lecture, 3 hours; laboratory, 3 hours.

Analysis and design of single stage and multistage transistor circuits at low and high frequencies. Transistor response. Analysis and design of feedback circuits. Stability criteria.

139. Probability and Statistics

 prerequisites: Open to Electrical Engineering, Computer Engineering and pre-Computer Engineering majors only. Lecture, 3 hours; discussion, 2 hours.

Fundamentals of probability, conditional probability, Bayes rule, random variables, functions of random variables, expectation and high-order moments, Markov chains, hypothesis testing.

141A. Introduction To Nanoelectromechanical and Microelectromechanical Systems (NEMS/MEMS)

 prerequisites: ME 16 & 17, ME 152A, ME 151A (may be concurrent); or ECE 130A and 137A with a minimum grade of C- in both.

Introduction to nano- and microtechnology. Scaling laws and nanoscale physics are stressed. Individual subjects at the nanoscale including materials, mechanics, photonics, electronics, and fluids will be described, with an emphasis on differences of behavior at the nanoscale and real-world examples.

141B. MEMS: Processing and Device Characterization

 prerequisites: ME 141A, ME 163 (may be concurrent); or ECE 141A.

Lectures and laboratory on semiconductor-based processing for MEMS. Description of key equipment and characterization tools used for MEMS and microfabrication. Characterization and testing of MEMS. Emphasis on current MEMS devices including accelerometers, comb drives, micro-reactors and actuator-actuators. (W)

141C. Introduction to Microfluidics and BioMEMS

 prerequisites: ME 141A or ECE 141A; open to ME and EE majors only.

Introduces physical phenomena associated with microscale/nanoscale fluid mechanics, microfluidics, and bioMEMS. Analytical methods and numerical simulation tools are used for analysis of microfluids.

142. Introduction to Power Electronics

 prerequisites: ECE 132, ECE 134, and ECE 137A with a minimum grade of C- in all; open to EE majors only. Lecture, 3 hours; laboratory, 2 hours.

An introduction to modern switched-mode power electronics and associated devices. Covers modern converter/inverter topologies for the control and conversion of electrical power with high efficiency with applications to power supplies, renewable energy systems, lighting, electric/hybrid vehicles, and motor drivers.

144. Electromagnetic Fields and Waves

 prerequisites: ECE 134 with a minimum grade of C-. Lecture, 3 hours; laboratory, 3 hours.

Waves on transmission lines, Maxwell’s equations, skin effect, propagation and reflection of electromagnetic waves, microwave integrated circuit principles, metal and dielectric waveguides, resonant cavities, antennas, Microwave and optical devices examples and experience with modern microwave and CAD software.

145A. Communication Electronics

 prerequisites: ECE 137A-B with a minimum grade of C- in both. Lecture, 3 hours; laboratory, 6 hours. RF/Microwave circuits. Transistor, transmission-line, and passive element characteristics. Transmission-line theory and microwave circuit matching. Amplifier design for maximum available gain. Amplifier stability. Gain compression and power limits. Introduction to noise figure, and intermodulation distortion.

145B. Communication Electronics II

 prerequisites: ECE 145A with a minimum grade of C-. EE majors only. Lecture, 3 hours; laboratory, 6 hours.


146C. Communication Electronics III

 prerequisites: ECE 145B with a minimum grade of C-. Lecture, 4 hours.


146A. Digital Communication Fundamentals

 prerequisites: ECE 130A-B with a minimum grade of C-; open to EE majors only. Lecture: 3 hours; Laboratory: 6 hours.

Signal and channel models, with emphasis on wireless systems, digital modulation, demodulation basics; statistical modeling of noise, including review of probability theory and random variables.

146B. Communication Systems Design

 prerequisites: ECE 130A-B and 146A with minimum grades of C-; open to EE majors only. Lecture: 3 hours; Laboratory: 6 hours.

Optical demodulation, including signal space geometry; communication performance characterization; advanced wireless communication techniques, including multi-antenna and multicarrier systems; other emerging frontiers in communications.

147A. Feedback Control Systems - Theory and Design

 prerequisites: ECE 130A-B with a minimum grade of C- in each; open to EE and computer engineering majors only. Lecture, 3 hours; laboratory, 6 hours.

Feedback systems design, specifications in time and frequency domains. Analysis and synthesis of closed loop systems. Computer aided analysis and design.

147B. Digital Control Systems - Theory and Design

 prerequisites: ECE 147A with a minimum grade of C-; open to EE and computer engineering majors only. Lecture, 3 hours; laboratory, 6 hours.

Analysis of sampled data feedback systems; state space description of linear systems; observability, controllability, pole assignment, state feedback, observers. Design of digital control systems. (W)

147C. Control System Design Project

 prerequisites: ECE 147A or ME 155B or ME 173 with a minimum grade of C-. Lecture, 3 hours; laboratory, 6 hours.

Students are required to design, implement, and document a significant control systems project. The project is implemented in hardware or in high-fidelity numerical simulators. Lectures and laboratories cover special topics related to the practical implementation of control systems.

148. Applications of Signal Analysis and Processing

 prerequisites: ECE 130A and 130B with a minimum grade of C- in both. Lecture: 3 hours; Discussion: 2 hours

Recommended Preparation: concurrent enrollment in ECE 130B.

A sequence of engineering applications of signal analysis and processing techniques; in communications, image processing, analog and digital filter design, signal detection and parameter estimation, holography and tomography, Fourier optics, and microwave and acoustic sensing.

149. Game Theory for Networked Systems

 prerequisites: UPPER DIVISION STANDING OR CONSENT OF INSTRUCTOR.

An overview of game theory with an emphasis on application to multi-agent systems. Game theory focuses on the study of systems that are comprised of interacting and possibly competing decision-making entities. Examples drawn from engineered, economics, and social systems.

150. Mobile Embedded Systems

 prerequisites: Proficiency in Java programming, and a C- in ECE 152A.

Architectures of modern smartphones and their key hardware components including mobile application processors, communications chips, display, touchscreen, graphics, camera, battery, GPS, and various sensors; the OS and software development platform of smartphones; smartphone applications; low power design techniques.

152A. Digital Design Principles

 prerequisites: ECE 15A and 2A or ECE 10A & ECE 10AL with a minimum grade of C- in each course; or Computer Science 30 or 64 with a minimum grade of C- in each course; open to electrical engineering, computer engineering, and computer science majors only. Lecture: 3 hours; Laboratory: 6 hours.

Design of synchronous digital systems: timing diagrams, propagation delay, latches and flip-flops, shift registers and counters, Mealy/Moore finite state machines, Verilog, 2-phase clocking, timing analysis, CMOS implementation, RAM, ROM-based designs, ASM charts, state minimization.

153A. Hardware/Software Interface

 prerequisites: Upper division standing in Computer Engineering, Computer Science or Electrical Engineering.

Same course as Computer Science 153A. Issues in interfacing computing systems and software to practical rapid response, real-time events and management of tasks, threads, and scheduling required for efficient design of embedded software and systems is discussed. Techniques for highly constrained systems.

153B. Sensor and Peripheral Interface Design

 prerequisites: ECE 152A with a minimum grade of C-. Lecture: 3 hours; Laboratory: 3 hours.

Hardware description languages; field-programmable logic and ASIC design techniques. Mixed-signal techniques: A/D and D/A converter interfaces; video and audio signal acquisition, processing and generation, communication and network interfaces.

154A. Introduction to Computer Architecture

 prerequisites: ECE 152A with a minimum grade of C-; open to EE and CMPEN majors only. Lecture: 3 hours; Discussion: 1 hour

Not open for credit to students who have completed Computer Science 154. ECE 154A is the
162B. Fundamentals of the Solid State (4) STAFF
Prerequisite: ECE 162A with a minimum grade of C-; open to EE, senior students in the BS/MS programs and Materials graduate students only.
Same course as Materials 162B. Lecture, 3 hours; discussion, 1 hour.

162C. Optoelectronic Materials and Devices (4) STAFF
Prerequisite: ECE 162A-B with a minimum grade of C-; open to electrical engineering and materials majors only. Lecture, 3 hours; discussion, 1 hour.

178. Introduction to Digital Image and Video Processing (4) STAFF
Prerequisites: open to EE, computer engineering, and computer science majors with upper-division standing. Lecture, 3 hours; discussion, 1 hour.
Basic concepts in image and video processing. Topics include image formation and sampling, image transforms, image enhancement, and image and video compression including JPEG and MPEG coding standards.

179D. Introduction to Robotics: Dynamics (4) BYL
Prerequisites: ECE 130A or EE 155A (may be taken concurrently). Not open for credit to students who have completed Mechanical Engineering 179D.
Introduction to robotics and mechanical systems. Lagrangian method for deriving equations of motion, introduction to the Jacobian, and modeling and control of forces and contact dynamics at a robotic end effector. Laboratories encourage a problem-solving approach to control.

189A. Senior Computer Systems Project (4) ISUKAPALLI
Prerequisite: ECE 189A; senior standing in Computer Engineering, Computer Science or EE. Lecture: 3 hours; Laboratory: 3 hours.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

189B. Senior Electrical Engineering Project (3) BEN YAACOV
Prerequisite: ECE 188A with a minimum grade of C-. Lecture: 3 hours; Laboratory: 3 hours.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

188A. Senior Electrical Engineering Project (3) BEN YAACOV
Prerequisite: ECE 130A and ECE 130B with a C-grade or better in both; or ECE 137A and ECE 137B with a C- or better in both.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.

188C. Senior Electrical Engineering Project (3) BEN YAACOV
Prerequisite: ECE 188B with a minimum grade of C-. Lecture: 3 hours; Laboratory: 3 hours.
Student groups design a significant project based on the knowledge and skills acquired in earlier coursework and integrate their technical knowledge through a practical design experience. The project is evaluated through written reports, oral presentations, and demonstrations of performance.
Student groups design a significant computer-based project. Focus will be on building and implementing an embedded hardware system. Each group works independently. The project is evaluated through project reports, achieving milestones and through successful demonstration of hardware functionality.

198C. Senior Computer Systems Project
(4) ISUKAPILLI
Prerequisite: ECE 198B; senior standing in Computer Engineering, Computer Science or EE. Lecture: 3 hours; Laboratory: 3 hours
Not open for credit to students who have completed Computer Science 199AA-B.
Student groups design a significant computer-based project. The focus in this course will be on the integration of both hardware and software components. Students continue to work in groups. Apart from project reports and presentations, the evaluation will be based on successful demonstration of both hardware and software aspects of the project.

192. Projects in Electrical and Computer Engineering
(4) STAFF
Prerequisite: consent of instructor. Discussion, 2 hours, laboratory: 6 hours.
Projects in electrical and computer engineering for advanced undergraduate students.

193. Internship in Industry
(1-8) STAFF
Prerequisite: consent of department.
Must have a 3.0 grade-point-average. May not be used as departmental electives. May be repeated to a maximum of 12 units. Field: 1-8 hours.
Special projects for selected students. Offered in conjunction with engineering practice in selected industrial and research firms, under direct faculty supervision.

194AA-ZZ. Special Topics in Electrical and Computer Engineering
(1-5) STAFF
Prerequisite: consent of instructor. Variable hours.

196. Undergraduate Research
(2-4) STAFF
Prerequisites: upper-division standing; consent of instructor.
Must have a minimum 3.0 grade-point average for the preceding three quarters. May be repeated for up to 12 units. Not more than 4 units may be applied to departmental electives.
Research opportunities for undergraduate students. Students will be expected to give regular oral presentations, actively participate in a weekly seminar, and prepare at least one written report on their research.

199. Independent Studies in Electrical and Computer Engineering
(1-5) STAFF
Prerequisites: upper-division standing; completion of two upper-division courses in electrical and computer engineering; consent of instructor.
Must have a minimum 3.0 grade-point average for the preceding three quarters. Students are limited to five units per quarter and 30 units total in all 98/99/198/199/199DC/199RA courses combined.

Directed individual study, normally experimental.

GRADUATE COURSES
Graduate courses for this major can be found in the UCSB General Catalog.

Engineering Sciences

Engineering Sciences, Office of Associate Dean for Undergraduate Studies, Harold Frank Hall, Room 1006; Telephone (805) 969-2609
Web site: www.engineering.ucsb.edu/undergraduate/majors-programs/engineering-sciences

Chair & Associate Dean: Glenn E. Beltz
Faculty
Glenn E. Beltz, Ph.D., Harvard, Professor
Jeffrey M. Moehlis, Ph.D., University of California, Berkeley, Professor
Linda R. Petzold, Ph.D., University of Illinois at Urbana-Champaign, Professor
Tyler G. Susko, Lecturer Potential SOE
Robert York, Ph.D., Cornell University, Professor

The Engineering Sciences program at UCSB serves as a focal point for the cross-disciplinary educational environment that prevails in each of our five degree-granting undergraduate programs (chemical engineering, computer engineering, computer science, electrical engineering, and mechanical engineering). The courses offered in this department are designed to cultivate well-educated, innovative engineers and scientists with excellent management and entrepreneurial skills and attitudes oriented to new technologies.

One of the missions of the Engineering Sciences program is to provide coursework commonly needed across other educational programs in the College of Engineering. For example, courses in computer programming, computation, ethics, engineering writing, engineering economics, science communication to the public, and even an aeronautics-inspired art course are offered.

Engineering Sciences Courses

LOWER DIVISION

3. Introduction to Programming for Engineers
(3) MOEHLIS, PETZOLD
Prerequisites: Open to chemical engineering, electrical engineering, and mechanical engineering majors only.
General philosophy of programming and problem solving. Students will be introduced to the programming language MATLAB. Specific areas of study will include algorithms, basic decision structures, arrays, matrices, and graphing. (F, S, M).

99. Introduction to Research
(1-3) STAFF
Prerequisite: Consent of instructor.
May be repeated for credit to a maximum of 6 units. Students are limited to 5 units per quarter and 30 units total in all 98/99/198/199/199AA-ZZ courses combined. Directed study to be arranged with individual faculty members. Course offers exceptional students an opportunity to participate in a research group.

UPPER DIVISION

101. Ethics in Engineering
(3) STAFF
Prerequisite: senior standing in engineering.

103. Advanced Engineering Writing
(4) STAFF
Prerequisites: Writing 50 or 50E; upper-division standing.
Practice in the forms of communication—contractual reports, proposals, conference papers, oral presentations, business plans—that engineers and entrepreneurial engineers will encounter in professional careers. Focus is on research methods, developing a clear and persuasive writing style, and electronic document preparation.

160. Science for the Public
(1-4) STAFF
Prerequisite: consent of instructor.
Same course as Physics 160K. Open to graduate students in science and engineering disciplines and to undergraduate science and engineering majors. Provides experience in communicating science and technology to nonspecialists. The major components of the course are field work in mentoring, a biweekly seminar, presentations to precollege students and to adult nonscientists, and end-of-term research papers.

177. Art and Science of Aerospace Culture
(4) STAFF
Prerequisites: Open to all UCSB students.
Aeronautics-inspired art course are offered. The course prevails in each of our five degree-granting undergraduate programs (chemical engineering, computer engineering, computer science, electrical engineering, and mechanical engineering). The courses offered in this department are designed to cultivate well-educated, innovative engineers and scientists with excellent management and entrepreneurial skills and attitudes oriented to new technologies.

One of the missions of the Engineering Sciences program is to provide coursework commonly needed across other educational programs in the College of Engineering. For example, courses in computer programming, computation, ethics, engineering writing, engineering economics, science communication to the public, and even an aeronautics-inspired art course are offered.