Electrical and Computer Engineering (ECE)

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Program Mission Statement

To educate tomorrow's technology leaders.

Program Educational Objectives

- To provide our students with training in the fundamental science and mathematics that underlie engineering, and with a general breadth and depth in engineering and in engineering design so that they are prepared for graduate school and for engineering careers. Students should have both proficiency in a specific technical area, and the flexibility and broad knowledge base needed for life-long engineering careers in a changing technical environment.
- To ensure that our students are educated in the classical sense. In particular, that they are broadly aware of social and environmental issues and of the impact of their profession on these issues.
- To assist our students in preparing themselves to work effectively in their profession. Specifically, to develop communications, teamwork, and leadership skills.

Program Outcomes and Assessment

Program outcomes have been established based on the Program Educational Objectives. Graduates of the ECE Program in Electrical Engineering are expected to have:

1. An understanding of the underlying principles of, and an ability to apply knowledge of mathematics, science, and engineering to electrical engineering problems
2. An ability to design and conduct experiments, as well as to analyze and interpret data
3. A knowledge of electrical engineering safety issues
4. An ability to design a system, component, or process to meet desired needs

5a. An ability to collaborate effectively with others

5b. An ability to function on multidisciplinary teams

6. An ability to identify, formulate, and solve engineering problems
7. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice, including familiarity with computer programming and information technology
8. An understanding of professional and ethical responsibility

9a. An ability to communicate effectively in writing

9b. An ability to communicate effectively in speech

9c. An ability to communicate effectively with visual means

10. The broad education necessary to understand the impact of engineering solutions in a global and societal context
11. A recognition of the need for, and the ability to engage in, life-long learning
12. A knowledge of contemporary issues

The Undergraduate Programs

The Department of Electrical and Computer Engineering offers undergraduate programs leading to the B.S. degree in **electrical engineering, engineering physics,** and **computer engineering**. Each of these programs can be tailored to provide preparation for graduate study or employment in a wide range of fields. The Electrical Engineering Program is accredited by the Accreditation Board for Engineering and Technology (ABET).

The Electrical Engineering Program has a common lower-division and a very flexible structure in the upper-division. After the lower-division core, all students take six breadth courses during the junior year. They must then satisfy a depth requirement which can be met with five courses focused on some speciality, and a design requirement of at least one project course. The remainder of the program consists of six electives which may range as widely or as narrowly as needed.

The Engineering Physics Program is conducted in cooperation with the Department of Physics. Its structure is very similar to that of electrical engineering except the depth requirement includes seven courses and there are only four electives.

The Computer Engineering Program is conducted jointly with the Department of Computer Science and Engineering. It has a more prescribed structure. The program encompasses the study of hardware design, data storage, computer architecture, assembly languages, and the design of computers for engineering, information retrieval, and scientific research.

For information about admission to the program and about academic advising, students are referred to the section on ECE departmental regulations. In order to complete the programs in a timely fashion, students must plan their courses carefully, starting in their freshman year. Students should have sufficient background in high school mathematics so that they can take freshman calculus in the first quarter.

For graduation, each student must also satisfy general-education requirements determined by the student's college. The six colleges at UCSD require widely different numbers of general-education courses. Students should choose their college carefully, considering the special nature of the college and the breadth of education required. They should realize that some colleges require considerably more courses than others. Students wishing to transfer to another college should see their college adviser.

Graduates of community colleges may enter ECE programs in the junior year. However, transfer students should be particularly mindful of the freshman and sophomore course requirements when planning their programs.

These programs have strong components in laboratory experiments and in the use of computers throughout the curricula. In addition, the department is committed to exposing students to the nature of engineering design. This is accomplished throughout the curricula by use of open-ended homework problems, by exposure to engineering problems in lectures, by courses which emphasize student-initiated projects in both laboratory and computer courses, and finally by senior design-project courses in which teams of students work to solve an engineering design problem, often brought in from industry.

IT IS IMPERATIVE THAT STUDENTS DISCUSS THEIR CURRICULUM WITH THE APPROPRIATE DEPARTMENTAL ADVISER IMMEDIATELY UPON ENTRANCE TO UCSD, AND THEN AT LEAST ONCE A YEAR UNTIL GRADUATION.

B.S. Electrical Engineering Program

Students must complete 180 units for graduation, including the general-education requirements (GER). Note that 144 units (excluding GER) are required.

LOWER-DIVISION REQUIREMENTS (total of 68 units)

Mathematics (24 units): Math. 20A-B-C-D-E-F.

Physics (16 units): Phys. 2A-B-C-D or Phys. 4A-B-C-D-E. Math. 20A is a prerequisite for Phys. 2A. Students whose performance on the mathematics placement test permits them to start with Math. 20B or higher may take Phys. 2A in the fall quarter of the freshman year.

Chemistry (4 units): Chem. 6A.

Programming Course (4 units): ECE 15.

Electrical engineering (20 units): ECE 25, 30, 35, 45, and 65.

Additional Notes:

1. Students with AP math credit are strongly advised to take Math. 20B in the fall quarter, leaving room for a GER in the winter quarter.

2 The ECE undergraduate Web site shows several scheduling options. Please refer to the Web site and consult with the staff advisers in the undergraduate offices, rooms 2705 and 2707 in EBU1.

UPPER-DIVISION REQUIREMENTS (total of 76 units)

a. Electrical Engineering BREADTH Courses (24 units)

Courses required of all electrical engineering majors:

The six courses, ECE 101, 102, 103, 107, 108, and 109 are required of all electrical engineering majors and they are an assumed prerequisite for senior-level courses, even if they are not explicitly required. Although the courses are largely independent, there are some prerequisites. ECE 102 is a prerequisite for ECE 108. Students who delay some of the breadth courses into the spring should be careful that it does not delay their depth sequence.

b. Electrical Engineering DESIGN Course (4 units)

Note*: In order to fulfill the design requirement, students must complete one of the following courses with a grade C– or better.* ***Graduation will not be approved until a written copy of the design project is submitted to the ECE undergraduate office****.*

The electrical engineering design requirement can be fulfilled in any of the following three ways:

1. Take ECE 191: Engineering Group Design Project
2. Take ECE 192: Engineering Design
   This course requires the department stamp. Specifications and enrollment forms are available in the undergraduate office.
3. Take one of the following courses:
   - ECE 111: Advanced Digital Design Project
   - ECE 118: Computer Interfacing
   - ECE 155B or 155C: Digital Recording Projects
   - Phys. 121: Experimental Techniques

   Students who wish to take one of these courses to satisfy the design requirement must fill out an enrollment form and have departmental approval for the design credit prior to taking the course. The project must meet the same specifications as ECE 192.

c. Electrical Engineering ELECTIVES (28 units)

- Four engineering, mathematics, or physics courses, three of which must be upper division.
- Three additional electives which students may use to broaden their professional goals.

  (For additional information, please refer to the section on "Elective Policy for Electrical Engineering and Engineering Physics Majors.")

d. Electrical Engineering Depth Requirement (20 units)

Students must complete a "depth requirement" of at least five quarter courses to provide a focus for their studies. This set must include a clear chain of study of at least three courses which depend on the "breadth" courses. Students may choose one of the approved depth sequences listed below, or propose another with the approval of their faculty adviser. Some of the approved sequences have lower-division prerequisites and thus list six courses. Students choosing one of these sequences will have to complete only two "professional" electives. Guidelines for meeting the depth requirement can be obtained from the undergraduate office.

Electronics Circuits and Systems:
ECE 163, 164, 165, and any two of ECE 111, 118, 161A, 161B, 161C, and 166.

Electronic Devices and Materials:
ECE 135A, ECE 135B, 136L, 139, and 183.

Controls and Systems Theory:
ECE 171A, 171B, 174, 118, and 173.

Machine Intelligence:
ECE 173, 174, 172A and any two of ECE 175, 161A, 187, 253A, 285, and COGS 108F.

Photonics:
ECE 181, 182, 183, 184, and 185.

Communications Systems:
ECE 161A, 153, 154A-B-C.

Networks:
ECE 153, 159A, 159B, 158A-B.

Queuing Systems:
ECE 171A, 174, 159A-B, and Math. 181A.

Signal and Image Processing:
ECE 161A, 161B, 161C, 153, and ECE 172A or 174.

Computer Design:
CSE 12, 21, and 141, ECE 158A, 111 or 118, and 165.

Software Systems:
CSE 12, 21, 100, 101, 141, and 120.

B.S. Engineering Physics

Students must complete a total of 180 units for graduation, including the general-education requirements. Note that 146 units (excluding GER) are required.

All students will initially be placed in pre-major status. Upon successful completion of the following courses (with a minimum 2.0 GPA by the end of the first three quarters if a transfer student, six quarters if an incoming freshman), students will be admitted into full Engineering-Physics major status.

1. Math. 20A-B-C
2. Physics 2A-B
3. ECE 15, 25, and 35

To initiate the change from pre-major status to full major status, transfer students must see the ECE undergraduate adviser by the end of their third quarter at UCSD; incoming freshmen by the end of their sixth quarter.

Please refer to the sections "Undergraduate Regulations and Requirements" and "Acceptance to the Jacobs School of Engineering" for important details.

LOWER-DIVISION REQUIREMENTS (total of 70 units)

Mathematics (24 units): Math. 20A-B-C-D-E-F.

Physics (16 units): Phys. 2A-B-C-D or Phys. 4A-B-C-D-E. Math. 20A is a prerequisite for Phys. 2A. Students whose performance on the mathematics placement test permits them to start with Math. 20B or higher may take Phys. 2A in the fall quarter of the freshman year.

Physics Lab (2 units): Phys. 2DL is required.

Chemistry (4 units): Chem. 6A.

Programming Course (4 units): ECE 15.

Electrical engineering (20 units): ECE 25, 30, 35, 45, and 65.

Additional Notes:

1. Students with AP math credit are strongly advised to take Math. 20B in the fall quarter, leaving room for a GER in the winter quarter.
2. The ECE undergraduate Web site shows several scheduling options. Please refer to the Web site and consult with the staff advisers in the undergraduate offices, rooms 2705 and 2707 in EBU1.

UPPER-DIVISION REQUIREMENTS (76 units)

a. Engineering Physics BREADTH Courses (24 units)

The electrical engineering breadth courses ECE 101, 102, 103, 107, 108, and 109, are also required of engineering physics majors. However, because of the scheduling of Math. 110, Phys. 110A and 130A, they can only be taken in a specific order (please consult the ECE Web site).

b. Engineering Physics DESIGN Course (4 units)

Note*: In order to fulfill the design requirement, students must complete one of the following courses with a grade C– or better.* ***Graduation will not be approved until a written copy of the design project is submitted to the ECE undergraduate office.***

The engineering physics design requirement can be fulfilled in any of the following three ways:

1. Take ECE 191: Engineering Group Design Project
2. Take ECE 192: Engineering Design
   This course requires the department stamp. Specifications and enrollment forms are available in the undergraduate office.
3. Take one of the following courses:

- ECE 111: Advanced Digital Design Project
- ECE 118: Computer Interfacing
- ECE 155B or 155C: Digital Recording Projects
- Physics 121: Experimental Techniques

Students who wish to take one of these courses to satisfy the design requirement must fill out an enrollment form and have departmental approval for the design credit prior to taking the course. The project must meet the same specifications as ECE 192.

c. Engineering Physics ELECTIVES (20 units)

- Two engineering, mathematics, or physics courses, one of which must be upper division.
- Three additional electives which students may use to broaden their professional goals.

  (For additional information, please refer to the section on Elective Policy for Electrical Engineering and Engineering Physics Majors.)

d. Engineering Physics DEPTH Courses (28 Units)

All B.S. engineering physics students are required to take Phys. 110A, 130A-B, 140A, Math. 110, ECE 123 and 166; or ECE 135A and 135B; or ECE 182 and (181 or 183).

Elective Policy for Electrical Engineering and Engineering Physics Majors

1. Technical Electives:

Technical electives must be upper-division engineering, math or physics courses (except for the bioengineering track). Certain courses listed below are not allowed as electives because of overlap with ECE courses.

Physics: Students may not receive upper-division elective credit for any lower-division physics courses. Students may not receive credit for both Phys. 100A and ECE 107, Phys. 100B and ECE 107, Phys. 100C and ECE 123.

Mathematics: Math. 180A overlaps ECE 109 and 153, and therefore will not qualify for elective credit of either type. Math. 183 will not be allowed as an elective. Math. 163 will only be allowed as a professional elective. All lower-division mathematics is excluded from elective credit of either type.

Bioengineering: The following series of courses will provide “core” preparation in bioengineering and will satisfy five of the ECE technical elective requirements:

- BILD 1, BILD 2, BE 100, BE 140A-B.

The bioengineering department will guarantee admission to these courses for ECE students on a space available basis.

CSE: The following courses are excluded as electives: CSE 1, 2, 5A-B, 8A-B, 11, 123A (duplicates ECE 158A), 140 (duplicates ECE 25), 140L (duplicates ECE 25), 143 (duplicates ECE 165). CSE 12, 20, and 21 will count toward the three professional electives *ONLY*.

Mechanical and Aerospace Engineering (MAE): Credit will not be allowed for MAE 105, 139, 140, 143B, or 170.

Special Studies Courses 195–199: At most four units of 195–199 may be used for elective credit.

2. Professional Electives:

Normally these will be upper-division courses in engineering, mathematics, or physics. Students may also choose upper-division courses from other departments provided that they fit into a coherent professional program. In such cases, a lower-division prerequisite may be included in the electives. Courses other than upper-division engineering, mathematics, or physics must be justified in terms of such a program, and must be approved by a faculty adviser.

Biology and Chemistry: Of the three electives intended to allow for the professional diversity, one lower-division biology or chemistry course from BILD 1, 2, Chem. 6B-C may be counted for credit in combination with two upper-division biology or chemistry courses. Furthermore, this will count only if the student can demonstrate to a faculty adviser that they constitute part of a coherent plan for professional/career development.

Upper-division biology and chemistry courses will count toward the three professional electives but not the three math/physics/engineering electives.

Economics: Suitable electives would include:

Economics 1 followed by courses in one of the following tracks:

- Public and Environmental Economics: Select 2—Economics 118A-B, 130, 131, 132, 137.
- Labor and Human Resources: Select 2—Economics 136, 137, 138A-B, 139.
- Microeconomics: Economics 100A-B or 170A-B.
- Finance Track (MBA) I: Must complete all 3—Economics 4, 173, and another upper-division Economics elective.
- Finance Track (MBA) II: Economics 1, 100A or 170A, and 175.
- Operations Research: Must complete 172 A—Economics 172A and (172B or 172C).

Economics 3 followed by courses in one of the following tracks:

- Monetary Economics: Economics 111 and another upper-division Economics Elective.
- Macroeconomics: Economics 110A-B.

Note: *Economics 120A*, and *158A-B will not be allowed as professional electives*.

B.S. Computer Engineering

Students wishing to pursue the computer engineering curriculum must be admitted to either the ECE or CSE department. **The set of required courses and allowed electives is the same in both departments;** please note that the curriculum requires twenty upper-division courses. The Computer Engineering Program requires a total of 147 units (not including the general-education requirements).

The Computer Engineering Program offers a strong emphasis on engineering mathematics and other basic engineering science as well as a firm grounding in computer science. Students should have sufficient background in high school mathematics so that they can take freshman calculus in their first quarter. Courses in high school physics and computer programming, although helpful, are not required for admission to the program.

LOWER-DIVISION REQUIREMENTS (total of 70 units)

Mathematics (20 units): Math. 20A-B-C-D-F.

Physics (16 units): Phys. 2A-B-C-D, or Phys. 4A-B-C-D. Math. 20A is a prerequisite for Phys. 2A. Students whose performance on the mathematics placement test permits them to start with Math. 20B or higher may take Phys. 2A in the fall quarter of the freshman year.

Physics lab (2 units): Phys. 2BL or 2CL or 2DL. The lab course should be taken concurrently with the Phys. 2 or Phys. 4 sequence.

Computer Science (21 units): CSE 11 or 8B*, 12, CSE 20 or Math. 15A, CSE 21 or Math. 15B, CSE 30, and CSE 91.

* CSE 8A and CSE 8B are not required if a student completes CSE 11. CSE 11 is a faster paced version of CSE 8A and CSE 8B. Students will self-select which course they wish to take. Students without programming experience in a compiled language are advised to take CSE 8A and then CSE 8B instead of CSE 11.

Electrical Engineering (12 units): ECE 53A-B, ECE 109.

UPPER-DIVISION REQUIREMENTS (total of 76 units)

a. All B.S. computer engineering students are required to take CSE 100 or Math. 176, CSE 101 or Math. 188, CSE 105 or Math. 166, CSE 120, 131A-B, 140, 140L (CSE 140 and 140L must be taken concurrently), 141, 141L (CSE 141 and 141L must be taken concurrently).

b. In addition, all B.S. computer engineering students must fulfill the following upper-division ECE requirements:
   - Engineering Probability and Statistics ECE 109. This course can be taken in the sophomore year.
   - Electronic Circuits and Systems ECE 102 and 108. The department recommends that these courses be taken in the junior year.
   - Linear systems ECE 101 and 171A or 161A.

c. Technical electives: All B.S. computer engineering majors are required to take six technical electives.
   - One technical elective must be either ECE 111 or ECE 118.
   - Of the remaining five technical electives, four must be ECE or CSE upper-division or graduate courses.
   - The remaining course can be any upper-division course listed under the non-CSE/ECE electives. (See the section on electives below.)

Electives

The discipline of computer engineering interacts with a number of other disciplines in a mutually beneficial way. These disciplines include mathematics, computer science, and cognitive science. The following is a list of upper-division courses from these and other disciplines that can be counted as technical electives.

At most four units of 197, 198, or 199 may be used towards technical elective requirements. ECE/CSE 195 cannot be used towards course requirements. Undergraduate students must get instructor's permission and departmental stamp to enroll in a graduate course.

Students may not get duplicate credit for equivalent courses. The *UCSD General Catalog* should be consulted for equivalency information and any restrictions placed on the courses. Additional restrictions are noted below. Any deviation from this list must be petitioned.

Mathematics: All upper-division courses except Math. 168A-B, 179A-B, 183, 184A-B, 189A-B, and 195–199. If a student has completed CSE 167, then he or she cannot get elective credit for Math. 155A. Students may receive elective credit for only one of the following courses: CSE 164A, Math. 174, Math. 173, Phys. 105A-B, MAE 107, CENG 100. No credit for any of these courses will be given if Math. 170A-B-C is taken. Students will receive credit for either Math. 166 or CSE 105 (but not both), either Math. 188 or CSE 101 (but not both), and either Math. 176 or CSE 100 (but not both).

Computer Science and Engineering: All CSE upper-division courses except CSE 195. Students will receive credit for either CSE 123A or ECE 158A (but not both).

Cognitive Science: Sensation and Perception 101A, Learning, Memory, and Attention 101B, Language 101C, Distributed Cognition 102A, Cognitive Ethnography 102B, Cognitive Engineering 102C, Neuroanatomy and Physiology 107A, Systems Neuroscience 107B, Cognitive Neuroscience 107C, Programming Methods for Cognitive Science 108D, Neural Networks Models of Cognitive I 108E, Advanced Programming Methods for Cognitive Science 108F, Human Computer Interaction 120, Human Computer Interaction Programming 121, Semantics 150, Language Comprehension 153, Natural and Artificial Symbolic Representational Systems 170, Neural Network Models of Cognition II 181, Artificial Intelligence Modeling II 182.

Students may not get credit for both CSE 150 and Advanced Programming Methods for Cognitive Science 108F or for both CSE 151 and Artificial Intelligence Modeling II 182.

Mechanical and Aerospace Engineering (MAE): All upper-division MAE courses except MAE 140, and MAE 195-199.

Students may receive elective credit for only one of the following courses: CSE 164A, Math. 174, Math. 173, Phys. 105A-B, CENG 100, MAE 107. Students may only get credit for one of the two courses, CSE 167 or MAE 152.

Economics: Microeconomics 100A-B, Game Theory 109, Macroeconomics 110A-B, Mathematical Economics 113, Econometrics 120B-C, Applied Econometrics 121, Management Science Micro-economics 170A-B, Decisions Under Uncertainty 171, Introduction to Operations Research 172A-B-C, Economic and Business Forecasting 178.

Students cannot take Economics 120A since it duplicates ECE 109.

Linguistics: Phonetics 110, Phonology I 111, Phonology II 115, Morphology 120, Syntax I 121, Syntax II 125, Semantics 130, Mathematical Analysis of Languages 160, Computers and Language 163, Computational Linguistics 165, Psycholinguistics 170, Language and the Brain 172, and Sociolinguistics 175.

Engineering: Team Engineering 101 (see course description under the Jacobs School of Engineering section).

Music: Computer Music II 172, Audio Production: Mixing and Editing 173.

Psychology: Engineering Psychology 161.

Minor Curricula

ECE offers three minors in accord with the general university policy that a minor requires five upper-division courses. ***Students must realize that these upper-division courses have extensive lower-division prerequisites (please consult the ECE undergraduate office).*** Students should also consult their college provost's office concerning the rules governing minors and programs of concentration.

Electrical Engineering: 20 units chosen from the breadth courses ECE 101, 102, 103, 107, 108, 109.

Engineering Physics: 20 units chosen from the junior year courses Phys. 110A, 130A, Math. 110, ECE 101, 102, 103, 107, 108, 109.

Computer Engineering: 20 units chosen from the junior year courses ECE 102, 108, CSE 100, 101, 105, 120, 140, 140L, 141, 141L.

The department will consider other mixtures of upper-division ECE, CSE, physics, and mathematics courses by petition.

Undergraduate Admissions, Policies, and Procedures

Freshman eligibility

1. **Computer Engineering majors:**

   Admission to the computer engineering major is currently restricted as described in the section "Admission to the School of Engineering." The only way to become a computer engineering (CE) major is to be directly admitted as an entering freshman or as an entering transfer (Transfer students, see TRANSFER STUDENTS section below).

   The electrical and computer engineering department may periodically grant admission to the computer engineering (CE) major to a small number of academically exceptional UCSD undergraduate students who were not admitted to this major as entering students. Exceptional admission will be considered for students having an overall UCSD GPA of 3.5 or better who have taken at least two CSE, math, or science courses demonstrating special aptitude for the CE curriculum. Applications for exceptional admission must include submission of a course plan demonstrating ability to satisfy graduation requirements and a personal statement addressing the applicant's motivation to join the CE major, in addition to other criteria established by the department.

2. **Electrical Engineering:**

   Freshmen students who have excelled in high school and have declared electrical engineering on their application will be directly admitted by the dean of the School of Engineering into their major. The only way to become an electrical engineering major is to be directly admitted as an entering freshman (transfer students see *Transfer Students* section below). These students will be notified directly of their status.

   Because of heavy student interest in departmental programs and the limited resources available to accommodate this demand, maintenance of a high quality program makes it necessary to limit enrollment to the most qualified students.

   Admission to the department as a major, transfer, or minor is in accordance with the general requirements established by the School of Engineering.

   The electrical and computer engineering department may periodically grant admission to the electrical engineering (EE) major to a small number of academically exceptional UCSD undergraduate students who were not admitted to this major as entering students. Exceptional admission will be considered for students having an overall UCSD GPA of 3.5 or better who have taken at least two CSE, math, or science courses demonstrating special aptitude for the EE curriculum. Applications for exceptional admission must include submission of a course plan demonstrating ability to satisfy graduation requirements and a personal statement addressing the applicant's motivation to join the EE major, in addition to other criteria established by the department.

3. **Engineering Physics:**

All students will initially be placed in pre-major status. Upon successful completion of the following courses (with a minimum 2.0 GPA by the end of the first three quarters if a transfer student, six quarters if an incoming freshman), students will be admitted into full Engineering-Physics major status.

1. Math. 20A-B-C
2. Physics 2A-B
3. ECE 15, 25, and 35

To initiate the change from pre-major status to full major status, transfer students must see the ECE undergraduate adviser by the end of their third quarter at UCSD; incoming freshmen by the end of their sixth quarter.

Please refer to the sections "Undergraduate Regulations and Requirements" and "Acceptance to the Jacobs School of Engineering" for important details.

Transfer Students Eligibility

Effective **fall 2004**, it is **strongly recommended** that transfer students complete the following preparation for engineering majors*:

- Calculus I—for Science and Engineering (Math. 20A)
- Calculus II—for Science and Engineering (Math. 20B)
- Calculus and Analytic Geometry (Math. 20C)
- Differential Equations (Math. 20D)
- Linear Algebra (Math. 20F)
- Complete calculus-based physics series with lab experience (Physics 2A-B-C)
- Chemistry 6A (except Computer Science and Computer Engineering majors)
- Highest level of introductory computer programming language course offerings at the community college**

*Effective **fall 2006**, these courses will be **required** preparation for all engineering transfer students.

**Refer to the *UCSD General Catalog* to select major prerequisite requirement for computer language courses.

1. **Computer Engineering:**

   The B.S. in Computer Engineering is a heavily impacted major and admission is limited to applicants who have demonstrated a high level of achievement commensurate with the prospect of success in this major. Successful applicants must have completed substantial training at the community college and must have achieved a high level of academic performance there. For example, the required minimum of ninety quarter transfer units must include eighteen quarter units of calculus, twelve quarter units of calculus-based physics, and the highest level computer science course offered at their community college. Although the actual required GPA cutoff depends on the number of openings, at least a 3.2 GPA in the community college transfer courses, and a 3.4 GPA in math, physics and computer science courses, are likely to be needed to gain admission.

   When planning their programs, students should be mindful of lower-division prerequisites necessary for admission to upper-division courses.

   Effective fall 2004 applicants seeking admission as transfer students will be considered for direct admission into the Computer Engineering (CE) major in the Department of Electrical and Computer Engineering (ECE). The only way to become a Computer Engineering (CE) major is to be directly admitted as an entering transfer student.

2. **Electrical Engineering:**

   The B.S. in Electrical Engineering is heavily impacted and admission is limited to applicants who have demonstrated a high level of achievement commensurate with the prospect of success in these majors. Successful applicants must have completed substantial training at the community college and must have achieved high level of academic performance there. For example, the required minimum of 90 quarter transfer units must include 18 quarter units of calculus, 12 quarter units of calculus-based physics, and the highest level computer science course offered at their community college.

Effective fall 2004, applicants seeking admission as transfer students will be considered for direct admission into the electrical engineering major in the Department of Electrical Engineering. The only way to become an electrical engineering major is to be directly admitted as an entering transfer student. Although the actual required GPA cutoff depends on the number of openings, at least a 3.2 GPA in the community college transfer courses, and a 3.4 GPA in math, physics, and computer science courses, are likely to be needed to gain admission. Transfer students who have declared pre-electrical engineering will be considered for direct admission to the major.

There will be no pre-major admissions to Electrical Engineering.

The electrical engineering department may periodically grant admissionto the electrical engineering major to a small number of academically exceptional UCSD undergraduate students who were not admitted to these majors as entering students. Exceptional admission will be considered for students having an overall UCSD GPA of 3.5 or better who have taken at least two ECE, math, or science courses demonstrating special aptitude for the EE curriculum. Applications for exceptional admission must include submission of a course plan demonstrating ability to satisfy graduation requirements and a personal statement addressing the applicant's motivation to join the electrical engineering major, in addition to other criteria established by the department.

3. **Engineering Physics:**

   Students are accepted into the pre-major and must complete the following courses in order to be accepted into the engineering physics major: Math. 20A-B-C, Phys. 2A-B, ECE 15, 25, and 35. Students who wish to enter in the engineering physics major must contact the department before the beginning of the fall quarter, submitting course descriptions and transcripts for courses used to satisfy their lower-division requirements. Normally, admission will be for the fall quarter; students entering in the winter or spring quarter should be aware that scheduling difficulties may occur because upper-division sequences normally begin in the fall quarter.

Grade Requirement in the Major

Courses required for the major must be taken for a letter grade. All major courses must be completed with a grade of C– or better.

A GPA of 2.0 is required in all upper-division courses in the major, including technical electives. The grade of D will not be considered an adequate prerequisite for any ECE course and will not be allowed for graduation. The engineering design requirement must be completed with a grade of C– or better.

Advising

Students are required to complete an academic planning form and to discuss their curriculum with the appropriate departmental adviser immediately upon entrance to UCSD, and then every year until graduation. This is intended to help students in: a) their choice of depth sequence, b) their choice of electives, c) keeping up with changes in departmental requirements. A faculty adviser will be assigned by the ECE department undergraduate office.

New Transfer Students in Electrical Engineering and Engineering Physics

The entire curriculum is predicated on the idea of actively involving students in engineering from the time they enter as freshmen. The freshman course "Introduction to Engineering" has been carefully crafted to provide an overview of the engineering mindset with its interrelationships among physics, mathematics, problem solving, and computation. All later courses are specifically designed to build on this foundation. All transfer students should understand that the lower-division curriculum is demanding. **Transfer students will be required to take all lower-division requirements or their equivalent.**

- Transfer students should start with ECE 20A in the fall quarter. Transfer students will be allowed to take ECE 20B and 60A concurrently. The recommended schedule for the lower-division ECE course is as follows:

Recommended Schedule

FALL	WINTER	SPRING
ECE 20A	ECE 20B	ECE 60B
MAE 9 or (CSE 11 or 8B)*	ECE 60A	ECE 60L

* Please note that engineering physics students cannot take CSE 11 or 8A in the fall quarter of the freshman year. (The fall quarter enrollment in CSE courses is reserved for computer science and computer engineering majors.) CSE 8A and CSE 8B are not required if a student completes CSE 11. CSE 11 is a faster paced version of CSE 8A and CSE 8B. Students will self-select which course they wish to take. Students without programming experience in a compiled language are advised to take CSE 8A and the CSE 8B instead of CSE 11.

Note: ECE 30 requires MAE 9 or (CSE 11 or 8B) and ECE 20B as a prerequisite and thus should be taken in the spring quarter of the sophomore year, or in the fall quarter of the junior year, concurrently with two upper-division breadth courses.

New Transfer Students in Computer Engineering

Recommended Schedules

FALL	WINTER	SPRING
FIRST YEAR*		
CSE 11	CSE 12	CSE 30
CSE 20 (or Math. 15A)	CSE 21 (or Math. 15B)	ECE 109
CSE 91	ECE 53A	ECE 53B
FIRST YEAR**		
CSE 8A	CSE 8B	CSE 20 (or Math. 15A)
ECE 53A	ECE 53B	CSE 30
	CSE 12	ECE 109

* Recommended schedule for students with programming experience. This schedule will require students to get clearance from the CSE department to take CSE 8B and CSE 20 concurrently

** Recommended schedule for students with no programming experience. This schedule will require students to get clearance from the CSE department to take CSE 8B and CSE 12 in the winter quarter, and CSE 20 and CSE 30 concurrently in the spring quarter. CSE 21 should then be taken during the summer sessions or the following fall quarter.

Students who do not have any programming experience are encouraged to take the CSE 8A-B sequence instead of CSE 11. Experience has shown that most students who are not familiar with programming and take CSE 11 have to retake the class because the accelerated pace makes it difficult to learn the new material.

Note: *Transfer students are encouraged to consult with the ECE undergraduate office for academic planning upon entrance to UCSD.*

ECE Honors Program

The ECE Undergraduate Honors Program is intended to give eligible students the opportunity to work closely with faculty in a project, and to honor the top graduating undergraduate students.

Eligibility for Admission to the Honors Program:

1. Students with a minimum GPA of 3.5 in the major and 3.25 overall will be eligible to apply. Students may apply at the end of the winter quarter of their junior year and no later than the end of the second week of fall quarter of their senior year. No late applications will be accepted.
2. Students must submit a project proposal (sponsored by an ECE faculty member) to the honors program committee at the time of application.
3. The major GPA will include ALL lower-division required for the major and all upper-division required for the major that are completed at the time of application (a minimum of twenty-four units of upper-division course work).

Requirements for Award of Honors:

1. Completion of all ECE requirements with a minimum GPA of 3.5 in the major based on grades through winter quarter of the senior year.
2. Formal participation (i.e., registration and attendance) in the ECE 290 graduate seminar program in the fall quarter of their senior year.
3. Completion of an eight-unit approved honors project (ECE 193H: Honors Project) and submission of a written report **by the first day of spring quarter** of the senior year. This project must contain enough design to satisfy the ECE BS four-unit design requirement.
4. The ECE honors committee will review each project final report and certify the projects which have been successfully completed at the honors level.

Procedure for Application to the Honors Program:

Between the end of the winter quarter of their junior year and the second week of the fall quarter of their senior year, interested students must advise the department of their intention to participate by submitting a proposal for the honors project sponsored by an ECE faculty member. Admission to the honors program will be formally approved by the ECE honors committee based on GPA and the proposal.

Unit Considerations

Except for the two-unit graduate seminar, this honors program does not increase a participant's total unit requirements. The honors project will satisfy the departmental design requirement and students may use four units of their honors project course as a technical elective.

Five-Year B.S./M. Eng. Program

Undergraduates in the ECE department who have maintained a good academic record in both departmental and overall course work are encouraged to participate in the five-year B.S./M. Eng. program offered by the department. Participation in the program will permit students to complete the requirements for the M. Eng. degree within one year following receipt of the B.S. degree. Complete details regarding admission to and participation in the program are available from the ECE Undergraduate Affairs office.

Admission to the Program

Students should submit an application for the B.S./M. Eng. program, including three letters of recommendation, by the program deadline during the spring quarter of their junior year. Applications are available from the ECE Undergraduate Affairs office. No GRE's are required for application to the B.S./M. Eng. program. A GPA of at least 3.0 both overall and in the major and strong letters of recommendation are required to be considered for program admission.

In the winter quarter of the senior year, applications of students admitted to the program will be forwarded by the department to the UCSD Office of Graduate Studies and Research. Each student must submit the regular graduate application fee *prior to the application deadline* for their application to be processed. Students who have been accepted into the B.S./M. Eng. program will automatically be admitted for graduate study beginning the following fall provided they maintain an overall GPA through the winter quarter of the senior year of at least 3.0. Upper-division (up to twelve units) or graduate courses taken during the senior year that are not used to satisfy undergraduate course requirements may be counted towards the forty-eight units required for the M. Eng. degree.

Continuation in the Program

Once admitted to the B.S./M. Eng. program, students must maintain a 3.0 cumulative GPA in all courses through the winter quarter of the senior year and in addition must at all times maintain a 3.0 cumulative GPA in their graduate course work. Students not satisfying these requirements may be re-evaluated for continuation in the program.

Admission for graduate study through the B.S./M. Eng. program will be for the M. Eng. degree only. Undergraduate students wishing to continue towards the Ph.D. degree must apply and be evaluated according to the usual procedures and criteria for admission to the Ph.D. program.

Curriculum

Students in the five-year B.S./M. Eng. program must complete the same requirements as those in the regular M. Eng. program. Completion of the M. Eng. degree requirements within one year following receipt of the B.S. degree will generally require that students begin graduate course work in their senior year. All requirements for the B.S. degree should be completed by the end of the senior (fourth) year, and the B.S. degree awarded prior to the start of the fifth year. Courses taken in the senior year may be counted toward the B.S. requirements or the M. Eng. degree requirements, but not both. *Students must have received their B.S. degree before they will be eligible to enroll as graduate students in the department.*

The Graduate Programs

The department offers two distinct graduate programs, the Ph.D. and the M. Eng. The Ph.D. program is strongly research oriented and is for students whose final degree objective is the Ph.D. If a student with a B.S. is admitted to this program, he or she will be expected to complete the requirements for the M.S. degree (outlined below) before beginning doctoral research. By contrast, the M. Eng. is intended to be a terminal professional degree, for those not planning to pursue the Ph.D. The M. Eng. has only a course-work requirement. Graduate applicants are admitted directly into the M. Eng. or the Ph.D. programs only.

In addition, the department offers M.S. and Ph.D. Programs in Computer Engineering jointly with CSE, and a Ph.D. Program in Applied Ocean Science jointly with MAE and Scripps Institution of Oceanography.

Admission to an ECE graduate program is in accordance with the general requirements of the UCSD graduate division, and requires at least a B.S. degree in engineering, physical sciences, or mathematics with a minimum upper division GPA of 3.0. Applicants must provide three letters of recommendation and recent GRE General Test scores. TOEFL scores are required from international applicants whose native language is not English. Applicants should be aware that the University does not permit duplication of degrees.

Support: The department makes every effort to provide financial support for Ph.D. students who are making satisfactory progress. Support may take the form of a fellowship, teaching assistantship, research assistantship, or some combination thereof. International students will not be admitted unless there is reasonable assurance that support can be provided for the duration of their Ph.D. program. Students in the M.Eng. programs may also obtain support through teaching or research assistantships, but this is less certain.

Advising: Students should seek advice on requirements and procedures from the departmental graduate office and/or the departmental Web site http://www.ece.ucsd.edu. All students will be assigned a faculty academic adviser upon admission and are strongly encouraged to discuss their academic program with their adviser immediately upon arrival and subsequently at least once per academic year.

Master of Engineering

The Master of Engineering (M. Eng.) program is intended primarily for engineers who desire Master's level work but do not intend to continue with Ph.D. level research. Salient features of the M. Eng. program include the following: It can be completed in four quarters at full-time or eight quarters at half time; it does not require a thesis, a research project, or a comprehensive exam; and it has an option of three courses in business, management, and finance.

Course Requirements:

The total course requirements are forty-eight units (twelve quarter courses). The choice of courses is subject to general focus and breadth requirements. Students will be assigned a faculty adviser who will help select courses.

1. **The Focus Requirement: (five courses)** The M. Eng. Program should reflect, among other things, a continuity and focus in one subject area. The course selection must therefore include at least twenty units (five quarter courses) in closely related courses leading to the state of the art in that area. The requirement may be met by selecting five courses from within one of the focus areas listed below. In some cases it may be appropriate to select five closely related courses from two of the areas listed below. Such cases must be approved by a faculty adviser and the ECE Graduate Affairs Committee.
2. **The Breadth Requirement: (two courses)** A graduate student often cannot be certain of his or her future professional career activities and may benefit from exposure to interesting opportunities in other subject areas. The breadth requirement is intended to provide protection against technical obsolescence, open up new areas of interest, and provide for future self-education and interaction with people from related and sometime disparate disciplines. The minimum breadth requirement is eight units (two quarter courses) of ECE/CSE graduate courses selected from among the courses listed below, in an area distinctly different from that of the focus requirement.
3. **Technical Electives: (two courses)** Two technical electives may be any graduate courses in ECE, CSE, Physics, or Mathematics. Other technical courses may be selected with the approval of the faculty adviser and the ECE Graduate Affairs Committee. Technical electives may include a maximum of four units of ECE 298 (Independent Study), or ECE 299 (Research).
4. **Professional Electives: (three courses)** The three professional electives may be used in several ways: for the IP/Core 401, 420, 421 series in business, management, and finance; for upper-division undergraduate technical courses specified as prerequisites for graduate-level focus, breadth, or technical elective courses taken to satisfy the M.Eng. degree requirements; or for additional graduate technical electives. Use of other courses to satisfy the Professional Elective requirement must be approved by the faculty adviser.

Scholarship Requirement: The forty-eight units of required course work must be taken for a letter grade (A-F), except for ECE 298 or 299, for which only S/U grades are allowed. Courses for which a D or F is received may not be counted. Students must maintain a GPA of 3.0 overall.

Master of Engineering Program Focus Courses

Please consult the ECE graduate office or the ECE Web site http://www.ece.ucsd.edu for the current list of focus areas and courses.

1. **Applied Physics**

   Allied Ph.D. research areas: Applied Physics—Applied Optics, Applied Physics—Electronic Devices and Materials, Photonics, Radio Space Science, and Magnetic Recording.

   ECE 222A-B-C. Electromagnetic Theory

   ECE 230A-B-C. Solid State Electronics

   ECE 236A-B-C-D. Semiconductors

   ECE 238A-B. Materials Science

   MS 201A-B-C. Materials Science

   ECE 240A-B-C. Optics

   ECE 241A-B-C. Optics

2. **Communications and Signal Analysis**

   Allied Ph.D. research areas: Communication Theory and Systems, Intelligent Systems, Robotics, and Control, Magnetic Recording, Signal and Image Processing.

   ECE 153. Random Processes

   ECE 250. Random Processes

   ECE 251AN-BN-CN-DN. Digital Signal Processing

   ECE 252A-B. Speech Compression and Recognition

ECE 253A-B. Digital Image Analysis

ECE 254. Detection Theory

ECE 255A. Information Theory

ECE 255B-C. Source Coding

ECE 256A-B. Time Series Analysis

ECE 257A-B. Wireless Communications

ECE 258A-B. Digital Communications

ECE 259AN-BN-CN. Channel Coding

ECE 273A-B-C. Optimization in Linear Vector Spaces

ECE 275A-B. Statistical Parameter Estimation

ECE 285. Special Topic: Computer Vision; Pattern Recognition (offerings vary annually)

3. Electronic Circuits and Systems

Allied Ph.D. Research areas: Computer Engineering, Electronic Circuits and Systems.

ECE 222A-B-C. Applied Electromagnetic Theory

ECE 230A-B-C. Solid State Electronics

ECE 236A-B-C. Semiconductor Heterostructure Materials

ECE 250. Random Processes

ECE 260A-B-C. VLSI Circuits

ECE 263A-B-C. Fault Tolerant Computing

ECE 264A-B-C. Analog IC Design

ECE 265A-B. Wireless Circuit Design

CSE 240A, 240B. Computer Architecture

CSE 242A, 243A. Computer Aided Design

Transferring to the Ph.D. program

Although the M. Eng. is intended as a terminal degree, the department recognizes that degree goals can change, including the possibility that a student admitted to the M. Eng. may wish to obtain a Ph.D. To this end, we outline below the procedure that must be followed to effect such a change. At the outset, however, we stress that this option should not be used in an attempt to circumvent the normal Ph.D. admissions process. Students who fail to meet the standards for the Ph.D. program at the time of admission have little chance of being allowed into the Ph.D. program at a later date.

Students in the M. Eng. program wishing to be considered for admission to the Ph.D. program should consult their academic adviser as soon as possible. Transfer from M. Eng. to the Ph.D. program is possible provided that the student satisfies the following requirements:

- Satisfy all requirements for initial admission to the Ph.D program, including submission of GRE General Test Scores, and be approved for consideration for transfer to the Ph.D program by the ECE Graduate Admissions Committee.
- Identify a faculty member who agrees, in writing, to serve as that student's academic and Ph.D. research adviser.
- In consultation with the academic adviser, design and complete a program of coursework that satisfies all course requirements and constraints for a Ph.D. discipline appropriate to their research. All students in the Ph.D. programs are required to satisfy all Ph.D. degree requirements as described below. Should the student not be admitted to the Ph.D. program, this program of coursework will serve, with the approval of the academic adviser and the ECE Graduate Affairs Committee, to satisfy the coursework requirements for the M. Eng. degree.
- Pass the comprehensive examination (Ph.D. Preliminary) at the level required for continuation in the Ph.D. program. A student failing to pass the comprehensive exam at this required level will not be admitted to the Ph.D. program, and will instead continue in the M. Eng. degree program.
- Maintain a GPA of at least 3.4 in the appropriate core graduate courses.

A student who has fulfilled all of the above requirements should, after passing the departmental comprehensive exam, submit a petition to change their degree objective from M. Eng. to Ph.D.

Master of Science

The ECE department offers an M.S. programs in electrical and computer engineering. The M.S. program in computer engineering is jointly administered with the Department of Computer Science and Engineering. The M.S. programs are research oriented, are intended to provide the intensive technical preparation necessary for subsequent pursuit of a Ph.D. It is stressed that the M.S. degree is offered only to students who have been admitted to the Ph.D. program. The M.S. degree may be earned either with a thesis (Plan 1) or with a research project followed by a comprehensive examination (Plan 2). However, continuation in the Ph.D. program requires a comprehensive examination so most students opt for Plan 2.

Course Requirements:

The total course requirements for the master of science degrees in electrical engineering and in computer engineering are forty-eight units (twelve quarter courses) and forty-nine units, respectively, of which at least thirty-six units must be in graduate courses. Note that this is greater than the minimum requirements of the university. The department maintains a list of core courses for each disciplinary area from which the thirty-six graduate course units must be selected. The current list may be obtained from the department graduate office or the official Web site of the department. Students in interdisciplinary programs may select other core courses with the approval of their academic adviser. The course requirements must be completed within two years of full-time study. Students will be assigned a faculty adviser who will help select courses and approve their overall academic curriculum.

Scholarship Requirement: The forty-eight units of required course work must be taken for a letter grade (A-F), except for graduate research (e.g. ECE 298, 299) for which only S/U grades are allowed. Courses for which a D or F is received may not be counted. Students must maintain a GPA of 3.0 overall.

Thesis and Comprehensive Requirements: The department offers both M.S. Plan 1 (thesis) and M.S. Plan 2 (comprehensive exam). Students in the M.S. program may elect either Plan 1 or Plan 2 any time. Students in the M.S. Plan 1 (thesis) must take twelve units of ECE 299 (Research) and must submit a thesis as described in the general requirements of the university. Students in the M.S. Plan 2 (comprehensive exam) must find a faculty member who will agree to supervise the student in a research project. This should be done before the start of the second year of study. They should complete at least four units of ECE 299 (Research) and must pass the departmental comprehensive examination by the end of their second year of study. This is an oral exam in which the student presents his or her research to a committee of three ECE faculty members, and is examined orally on a two-quarter core sequence in ECE. The outcome of the exam is based on the student's research presentation, proficiency demonstrated in the student's area of specialization, and overall academic record and performance in the graduate program.

Students in the computer engineering discipline may elect to take two written examinations in the Department of Computer Science and Engineering, in accordance with the CSE guidelines, in place of the oral examination on a two-quarter sequence in ECE. They are then required to give a thirty- to forty-five minute research presentation in the ECE department.

The Doctoral Programs

The ECE department offers graduate programs leading to the Ph.D. degree in ten disciplines within electrical and computer engineering, as described in detail below. The Ph.D. is a research degree requiring completion of the Ph.D. program course requirements, satisfactory performance on the comprehensive (Ph.D. Preliminary) examination and University Qualifying Examination, and submission and defense of a doctoral thesis (as described under the "Graduate Studies" section of this catalog). Students in the Ph.D. program must pass the comprehensive exam (Ph.D. Preliminary) before the beginning of the third year of graduate study. To ensure timely progress in their research, students are strongly encouraged to identify a faculty member willing to supervise their doctoral research by the end of their first year of study.

Students should begin defining and preparing for their thesis research as soon as they have passed the comprehensive exam (Ph.D. Preliminary). They should plan on taking the University Qualifying Examination about one year later. The University does not permit students to continue in graduate study for more than four years without passing this examination. At the Qualifying Examination the student will give an oral presentation on research accomplishments to date and the thesis proposal to a campus-wide committee. The committee will decide if the work and proposal has adequate content and reasonable chance for success. They may require that the student modify the proposal and may require a further review.

The final Ph.D. requirements are the submission of a dissertation and the dissertation defense (as described under the "Graduate Studies" section of this catalog).

Course Requirements: The total course requirements for the Ph.D. degree in electrical engineering are essentially the same as the M.S. degree and consists of forty-eight units (twelve quarter courses), of which at least thirty-six units must be in graduate courses. Note that this is greater than the minimum requirements of the university. The department maintains a list of core courses for each disciplinary area from which the thirty-six graduate course units must be selected. The current list may be obtained from the ECE department graduate office or the official Web site of the department. Students in the interdisciplinary programs may select other core courses with the approval of their academic adviser. The course requirements must be completed within two years of full-time study.

Students in the Ph.D programs may count no more than eight units of ECE 299 towards their course requirements.

Students who already hold an M.S. degree in electrical engineering must nevertheless satisfy the requirements for the core courses. However, graduate courses taken elsewhere can be substituted for specific courses with the approval of the academic adviser.

Scholarship Requirement: The forty-eight units of required courses must be taken for a letter grade (A-F), except for eight units of ECE 299 (Research) for which only S/U grades are allowed. Courses for which a D or F is received may not be counted. Students must maintain a GPA of 3.0 overall. In addition, a GPA of 3.4 in the core graduate courses is generally expected.

Comprehensive Exam (Ph.D. Preliminary): Ph.D. students must find a faculty member who will agree to supervise their thesis research. This should be done before the start of the second year of study. They should then devote at least half their time to research and must pass the comprehensive examination (Ph.D. Preliminary) by the end of their second year of study.* This is an oral exam in which the student presents his or her research to a committee of three ECE faculty members, and is examined orally for proficiency in his or her area of specialization. The outcome of the exam is based on the student's research presentation, proficiency demonstrated in the student's area of specialization, and overall academic record and performance in the graduate program. Successful completion of the comprehensive examination (Ph.D. Preliminary) will also satisfy the M.S. Plan 2 comprehensive exam requirement.

* Students in the computer engineering discipline may elect to take two written examinations in the Department of Computer Science and Engineering, in accordance with the CSE guidelines, in place of the oral examination on a two-quarter sequence in ECE. They are then required to give a thirty to forty-five minute research presentation in the ECE department.

University Qualifying Exam: Students who have passed the comprehensive exam (Ph.D. Preliminary) should plan to take the University Qualifying Examination approximately a year after passing the comprehensive exam (Ph.D. Preliminary). The University does not permit students to continue in graduate study for more than four years without passing this examination. The University Qualifying Examination is an oral exam in which the student presents his or her thesis proposal to a university-wide committee. After passing this exam the student is "advanced to candidacy."

Dissertation Defense: The final Ph.D. requirements are the submission of a dissertation, and the dissertation defense (as described under the Graduate Studies section of this catalog). Students who are advanced to candidacy may register for any ECE course on an S/U basis.

Departmental Time Limits: Students who enter the Ph.D. program with an M.S. degree from another institution are expected to complete their Ph.D. requirements a year earlier than B.S. entrants. They must discuss their program with an academic adviser in their first quarter of residence. If their Ph.D. program overlaps significantly with their earlier M.S. work, the time limits for the comprehensive and qualifying exams will also be reduced by one year. Specific time limits for the Ph.D. program, assuming entry with a B.S. degree, are as follows:

1. **The Comprehensive Exam (Ph.D. Preliminary)** must be completed before the start of the third year of full-time study.
2. **The University Qualifying Exam** must be completed before the start of the fifth year of full-time study.
3. **Support Limit:** Students may not receive financial support through the University for more than seven years of full-time study (six years with an M.S. degree).

4. **Registered Time Limit:** Students may not register as graduate students for more than eight years of full-time study (seven years with an M.S. degree).

   Half-Time Study: Time limits are extended by one quarter for every two quarters of approved half-time status. Students on half-time status may not take more than 6 units each quarter.

Ph.D. Research Programs:

1. **Applied Ocean Sciences:** This program in applied science related to the oceans is interdepartmental with the Graduate Department of the Scripps Institution of Oceanography (SIO) and the Department of Mechanical and Aerospace Engineering (MAE). It is administered by SIO. All aspects of man's purposeful and unusual intervention into the sea are included. The M.S. degree is not offered in this program.
2. **Applied Physics—Applied Optics and Photonics:** These programs encompass a broad range of interdisciplinary activities involving optical science and engineering, optical and optoelectronic materials and device technology, communications, computer engineering, and photonic systems engineering. Specific topics of interest include ultrafast optical processes, nonlinear optics, quantum cryptography and communications, optical image science, multidimensional optoelectronic I/O devices, spatial light modulators and photodetectors, artificial dielectrics, multifunctional diffractive and micro-optics, volume and computer-generated holography, optoelectronic and micromechanical devices and packaging, wave modulators and detectors, semiconductor-based optoelectronics, injection lasers, and photodetectors. Current research projects are focused on applications such as optical interconnects in high-speed digital systems, optical multidimensional signal and image processing, ultrahigh-speed optical networks, 3D optical memories and memory interfaces, 3D imaging and displays, and biophotonic systems. Facilities available for research in these areas include electron-beam and optical lithography, material growth, microfabrication, assembly, and packaging facilities, cw and femtosecond pulse laser systems, detection systems, optical and electro-optic components and devices, and electronic and optical characterization and testing equipment.
3. **Communication Theory and Systems** Communications theory and systems concerns the transmission, processing, and storage of information. Topics covered by the group include wireless and wireline communications, spread-spectrum communication, multi-user communication, network protocols, error-correcting codes for transmission and magnetic recording, data compression, time-series analysis, and image and voice processing.
4. **Computer Engineering** consists of balanced programs of studies in both hardware and software, the premise being that knowledge and skill in both areas are essential both for the modern-day computer engineer to make the proper unbiased trade-offs in design, and for researchers to consider all paths towards the solution of research questions and problems. Toward these ends, the programs emphasize studies (course work) and competency (comprehensive examinations, and dissertations or projects) in the areas of VLSI and logic design, and reliable computer and communication systems. Specific research areas include: computer systems, signal processing systems, multiprocessing and parallel and distributed computing, computer communications and networks, computer architecture, computer-aided design, fault-tolerance and reliability, and neurocomputing. The faculty is composed of interested members of the Departments of Electrical and Computer Engineering (ECE), Computer Science and Engineering (CSE), and related areas. The specialization is administered by both departments; the requirements are similar in both departments, with students taking the comprehensive exam, if necessary, given by the student's respective department.
5. **Electronic Circuits and Systems:** This program involves the study and design of analog, mixed-signal (combined analog and digital), and digital electronic circuits and systems. Emphasis is on the development, analysis, and implementation of integrated circuits that perform analog and digital signal processing for applications such as wireless and wireline communication systems, test and measurement systems, and interfaces between computers and sensors. Particular areas of study currently include radio frequency (RF) power amplifiers, RF low noise amplifiers, RF mixers, fractional-N phase-locked loops (PLLs) for modulated and continuous-wave frequency synthesis, pipelined analog-to-digital converters (ADCs), delta-sigma ADCs and digital-to-analog converters (DACs), PLLs for clock recovery, adaptive and fixed continuous-time, switched-capacitor, and digital filters, echo cancellation circuits, adaptive equalization circuits, wireless receiver and transmitter linearization circuits, mixed-signal baseband processing circuits for wireless transmitters and receivers, high-speed digital circuits, and high-speed clock distribution circuits.
6. **Applied Physics—Electronic Devices and Materials:** This program addresses the synthesis and characterization of advanced electronic materials, including semiconductors, metals, and dielectrics, and their application in novel electronic, optoelectronic, and photonic devices. Emphasis is placed on exploration of techniques for high-quality epitaxial growth of semiconductors, including both molecular-beam epitaxy (MBE) and metalorganic chemical vapor deposition (MOCVD); fabrication and characterization of materials and devices at the nanoscale; development of novel materials processing and integration techniques; and high-performance electronic devices based on both Group IV (Si/SiGe) and III-V compound semiconductor materials. Areas of current interest include novel materials and high-speed devices for wireless communications; electronic and optoelectronic devices for high-speed optical networks; high-power microwave-frequency devices; nanoscale CMOS devices and circuits; heterogeneous materials integration; novel device structures for biological and chemical sensing; advanced tools for nanoscale characterization and metrology; and novel nanoscale electronic, optoelectronic, and photonic devices. Extensive facilities are available for research i n this area, including several MBE and MOCVD systems; a complete microfabrication facility; electron-beam lithography and associated process tools for nanoscale fabrication; a Rutherford backscattering system; x-ray diffractometers; electron microscopy facilities; extensive scanning-probe instrumentation; cryogenic systems; and comprehensive facilities for DC to RF electrical device characterization and optical characterization of materials and devices.

7. **Intelligent Systems, Robotics, and Control:** This information sciences-based field is concerned with the design of human-interactive intelligent systems that can sense the world (defined as some specified domain of interest); represent or model the world; detect and identify states and events in the world; reason about and make decisions about the world; and/or act on the world, perhaps all in real-time. A sense of the type of systems and applications encountered in this discipline can be obtained by viewing the projects shown at the Web site http://swiftlet.ucsd.edu.

   The development of such sophisticated systems is necessarily an interdisciplinary activity. To sense and succinctly represent events in the world requires knowledge of signal processing, computer vision, information theory, coding theory, and data-basing; to detect and reason about states of the world utilizes concepts from statistical detection theory, hypothesis testing, pattern recognition, time series analysis, and artificial intelligence; to make good decisions about highly complex systems requires knowledge of traditional mathematical optimization theory and contemporary near-optimal approaches such as evolutionary computation; and to act upon the world requires familiarity with concepts of control theory and robotics. Very often learning and adaptation are required as either critical aspects of the world are poorly known at the outset, and must be refined online, or the world is non-stationary and our system must constantly adapt to it as it evolves. In addition to the theoretical information and computer science aspects, many important hardware and software issues must be addressed in order to obtain an effective fusion of a complicated suite of sensors, computers, and problem dynamics into one integrated system.

   Faculty affiliated with the ISRC subarea are involved in virtually all aspects of the field, including applications to intelligent communications systems; advanced human-computer interfacing; statistical signal- and image-processing; intelligent tracking and guidance systems; biomedical system identification and control; and control of teleoperated and autonomous multiagent robotic systems.

8. **Magnetic Recording** is an interdisciplinary field involving physics, material science, communications, and mechanical engineering. The physics of magnetic recording involves studying magnetic heads, recording media, and the process of transferring information between the heads and the medium. General areas of investigation include: nonlinear behavior of magnetic heads, very high frequency loss mechanisms in head materials, characterization of recording media by micromagnetic and many body interaction analysis, response of the medium to the application of spatially varying vectorial head fields, fundamental analysis of medium nonuniformities leading to media noise, and experimental studies of the channel transfer function emphasizing nonlinearities, interferences, and noise. Current projects include numerical simulations of high density digital recording in metallic thin films, micromagnetic analysis of magnetic reversal in individual magnetic particles, theory of recorded transition phase noise and magnetization induced nonlinear bit shift in thin metallic films, and analysis of the thermal-temporal stability of interacting fine particles.

   Research laboratories are housed in the Center for Magnetic Recording Research, a national center devoted to multi-disciplinary teaching and research in the field.

9. **Radio and Space Science:** The Radio Science Program focuses on the study of radio waves propagating through turbulent media. The primary objectives are probing of otherwise inaccessible media such as the solar wind and interstellar plasma. Techniques for removing the effects of the turbulent medium to restore the intrinsic signals are also studied.

   The Space Science Program is concerned with the nature of the sun, its ionized and supersonic outer atmosphere (the solar wind), and the interaction of the solar wind with various bodies in the solar system. Theoretical studies include: the interaction of the solar wind with the earth, planets, and comets; cosmic dusty-plasmas; waves in the ionosphere; and the physics of shocks. A major theoretical effort involves the use of supercomputers for modeling and simulation studies of both fluid and kinetic processes in space plasmas.

   Students in radio science will take measurements at various radio observatories in the U.S. and elsewhere. This work involves a great deal of digital signal processing and statistical analysis. All students will need to become familiar with electromagnetic theory, plasma physics, and numerical analysis.

10. **The Signal and Image Processing** Program explores engineering issues related to the modeling of signals starting from the physics of the problem, developing and evaluating algorithms for extracting the necessary information from the signal, and the implementation of these algorithms on electronic and opto-electronic systems. Examples of research areas include filter design, fast transforms, adaptive filters, spectrum estimation and modeling, sensor array processing, image processing, image restoration, video processing, pattern recognition, and the implementation of signal processing algorithms using appropriate technologies. Signal and image processing techniques have found application in a number of areas such as sonar, radar, speech, geophysics, medical imaging, robotic vision, digital communications, and multimedia systems among others.

Research Facilities

Most of the research laboratories of the department are associated with individual faculty members or small informal groups of faculty. Larger instruments and facilities, such as those for electron microscopy and e-beam lithography are operated jointly. In addition the department operates several research centers and participates in various university wide organized research units.

The department-operated research centers are the NSF Industrial/University Cooperative Research Center (I/UCRC) for Ultra-High Speed Integrated Circuits and Systems (ICAS); Opto-electronics Technology Center (OTC) sponsored by the Advanced Project Research Agency; the Center for Wireless Communications which is a university-industry partnership; and the Institute for Neural Computation.

Department research is also associated with the Center for Astronomy and Space Science, the Center for Magnetic Recording Research, the California Space Institute, the Institute for Nonlinear Science, and Calit2 (http://www.calit2.net). Departmental researchers also use various national and international laboratories, such as the National Nanofabrication Facility and the National Radio Astronomy Laboratory.

The department emphasizes computational capability and maintains numerous computer laboratories for instruction and research. One of the NSF national supercomputer centers is located on the campus. This is particularly useful for those whose work requires high data bandwidths.

COURSES

The department will endeavor to offer the courses as outlined below; however, unforeseen circumstances sometimes require a change of scheduled offerings. Students are strongly advised to check the *Schedule of Classes* or the department before relying on the schedule below. The names appearing below the course descriptions are those of faculty members in charge of the course. For the names of the instructors who will teach the course, please refer to the quarterly *Schedule of Classes*. The departmental Web site http://www.ece.ucsd.edut includes the present best estimate of the schedule of classes for the entire academic year.

LOWER-DIVISION

1A-B-C. Mesa Orientation Course (1-1-1)
Students will be given an introduction to the engineering profession and our undergraduate program. Exercises and practicums will develop the problem-solving skills needed to succeed in engineering. *Prerequisite: none.* (F,W,S)

15. Engineering Computation (4)
Students learn the C programming language with an emphasis on high-performance numerical computation. The commonality across programming languages of control structures, data structures, and I/O is also covered. Techniques for using MatLab to graph the results of C computations are developed. *Prerequisites: a familiarity with basic mathematics such as trigonometry functions and graphing is expected but this course assumes no prior programming knowledge.* (F,W,S)

25. Introduction to Digital Design (4)
This course emphasizes digital electronics. Principles introduced in lectures are used in laboratory assignments, which also serve to introduce experimental and design methods. Topics include Boolean algebra, combination and sequential logic, gates and their implementation in digital circuits. *Prerequisite: none.* (F,W,S)

30. Introduction to Computer Engineering (4)
The fundamentals of both the hardware and software in a computer system. Topics include: representation of information, computer organization and design, assembly and microprogramming, current technology in logic design. (Students who have taken CSE 30 may not take ECE 30 for credit.) *Prerequisites: ECE 15 and 25 with grades of C- or better.* (F,S)

35. Introduction to Analog Design (4)
Fundamental circuit theory concepts, Kirchoff's voltage and current laws, Thevenin's and Norton's theorems, loop and node analysis, time-varying signals, transient first order circuits, steady-state simusoidal response. *Prerequisites: Math. 20A-B; Math. 20C may be taken concurrently.* (F,W,S)

45. Circuits and Systems (4)
Steady-state circuit analysis, first and second order systems, Fourier Series and Transforms, time domain analysis, convolution, transient response, Laplace Transform, and filter design. *Prerequisites: Math. 20A-B-C, ECE 15, and ECE 35.* (F,W,S)

53A. Fundamentals of Electrical Engineering I (4)
This is a coordinated lecture and laboratory course for students majoring in other branches of science and engineering. It covers analysis and design of passive and active circuits. The course emphasizes problem-solving and laboratory work on passive circuits. *Prerequisites: Math. 20C, Math. 20D must be concurrent, Phys. 2B or BS or 4C with grades of C– or better.* (F,W)

53B. Fundamentals of Electrical Engineering II (4)
This is a coordinated lecture and laboratory course for students majoring in other branches of science and engineering. It covers analog and digital systems and active circuit design. Laboratory work will include operational amplifiers, diodes and transistors. *Prerequisites: ECE 53A with a grade of C– or better.* (W,S)

65. Components and Circuits Laboratory (4)
In this course, students learn to model, simulate, and design simple circuits and account for interaction between components. Concept of feedback is emphasized. Labs are designed to highlight the differences among analytical solution, simulation, and measurements of the circuit. Each lab includes a design experiment. *Prerequisites: Math. 20A-B-C, ECE 15, and ECE 35.* (F,W,S)

87. Freshman Seminar (1)
The freshman seminar program is designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small seminar setting. Freshman seminars are offered in all campus departments and undergraduate colleges, and topics vary from quarter to quarter. Enrollment is limited to 15 to 20 students, with preference given to entering freshmen. *Prerequisite: none.*

90. Undergraduate Seminar (1)
This seminar class will provide a broad review of current research topics in both electrical engineering and computer engineering. Typical subject areas are signal processing, VLSI design, electronic materials and devices, radio astronomy, communications, and optical computing. *Prerequisite: none*. (F,W,S)

UPPER-DIVISION

101. Linear Systems Fundamentals (4)
Complex variables. Singularities and residues. Signal and system analysis in continuous and discrete time. Fourier series and transforms. Laplace and z-transforms. Linear Time Invariant Systems. Impulse response, frequency response, and transfer functions. Poles and zeros. Stability. Convolution. Sampling. Aliasing. *Prerequisites: ECE 60B or ECE 53B with grades of C– or better.* (F,W)

102. Introduction to Active Circuit Design (4)
Nonlinear active circuits design. Nonlinear device models for diodes, bipolar and field-effect transistors. Linearization of device models and small signal equivalent circuits. Circuit designs will be simulated by computer and tested in the laboratory. (Lab fee: $15) *Prerequisites: ECE 60B and 60L or ECE 53B with grades of C– or better.* (F,W)

103. Fundamentals of Devices and Materials (4)
Introduction to semiconductor materials and devices. Semiconductor crystal structure, energy bands, doping, carrier statistics, drift and diffusion. p-n junctions, metal-semiconductor junctions. Bipolar junction transistors: current flow, amplification, switching, nonideal behavior Metal-oxide-semiconductor structures, MOSFETs, device scaling. *Prerequisites: Phys. 2D or Phys. 4D and 4E with grades of C– or better.* (F,W)

107. Electromagnetism (4)
Electrostatics and magnetostatics; electrodynamics; Maxwell's equations; plane waves; skin effect. Electromagnetics of transmission lines: reflection and transmission at discontinuities, Smith chart, pulse propagation, dispersion. Rectangular waveguides. Dielectric and magnetic properties of materials. Electromagnetics of circuits. *Prerequisites: Phys. 2A-D or 4A-E and ECE 60B or 53B with grades of C– or better.* (F,W)

108. Digital Circuits (4)
Digital integrated electronic circuits for processing technologies. Analytical methods for static and dynamic characteristics. MOS field-effect transistors and bipolar junction transistors, circuits for logic gates, flip-flop, data paths, programmable logic arrays, memory elements. (Lab fee: $15) *Prerequisites: Math 20A-B, 21C-D, 20F-E; Phys. 2A-D or 4A-E; (ECE 20A-B, 30, ECE 60A-B-L) or (ECE 53A and 53B); ECE 30 or CSE 30; ECE 102 with grades of C– or better.* (W,S)

109. Engineering Probability and Statistics (4)
Axioms of probability, conditional probability, theorem of total probability, random variables, densities, expected values, characteristic functions, transformation of random variables, central limit theorem. Random number generation, engineering reliability, elements of estimation, random sampling, sampling distributions, tests for hypothesis. Students who completed Math. 180A-B, Math. 183, or Economics 120A will not receive credit for ECE 109. *Prerequisites: Math. 20A-B-C or 21C, 20D or 21D, 20F, with grades of C– or better. (ECE 101 recommended).* (F,W,S)

111. Advanced Digital Design Project (4)
Advanced topics in digital circuits and systems. Use of computers and design automation tools. Hazard elimination, synchronous/asnychronous FSM synthesis, synchronization and arbitration, pipelining and timing issues. Problem sets and design exercises. A large-scale design project. Simulation and/or rapid prototyping. *Prerequisite: ECE 108 or CSE 140 with grades of C– or better.* (F,W,S)

118. Computer Interfacing (4)
Interfacing computers and embedded controllers to the real world: busses, interrupts, DMA, memory mapping, concurrency, digital I/O, standards for serial and parallel communications, A/D, D/A, sensors, signal conditioning, video, and closed loop control. Students design and construct an interfacing project. (Lab fee: $20) *Prerequisites: ECE 30 or CSE 30 and ECE 60A-B-L or ECE 53A-B.* (S)

120. Solar System Physics (4)
General introduction to planetary bodies, the overall structure of the solar system, and space plasma physics. Course emphasis will be on the solar atmos-

phere, how the solar wind is produced, and its interaction with both magnetized and unmagnitized planets (and comets). *Prerequisites: Phys. 2A-C or 4A-D, Math. 20A-B, 20C or 21C with grades of C- or better*. (S)

123. Antenna Systems Engineering (4)
The electromagnetic and systems engineering of radio antennas for terrestrial wireless and satellite communications. Antenna impedance, beam pattern, gain, and polarization. Dipoles, monopoles, paraboloids, phased arrays. Power and noise budgets for communication links. Atmospheric propagation and multipath. *Prerequisite: ECE 107 with a grade of C– or better.* (F)

134. Electronic Materials Science of Integrated Circuits (4)
Electronic materials science with emphasis on topics pertinent to microelectronics and VLSI technology. Concept of the course is to use components in integrated circuits to discuss structure, thermodynamics, reaction kinetics, and electrical properties of materials. *Prerequisites: Phys. 2C-D with grades of C– or better.* (S)

135A. Semiconductor Physics (4)
Crystal structure and quantum theory of solids; electronic band structure; review of carrier statistics, drift and diffusion, p-n junctions; nonequilibrium carriers, imrefs, traps, recombination, etc; metal-semiconductor junctions and heterojunctions. *Prerequisite: ECE 103 with a grade of C– or better*. (F)

135B. Electronic Devices (4)
Structure and operation of bipolar junction transistors, junction field-effect transistors, metal-oxide-semiconductor diodes and transistors. Analysis of dc and ac characteristics. Charge control model of dynamic behavior. *Prerequisite: ECE 135A with a grade of C– or better.* (W)

136. Fundamentals of Semiconductor Device Fabrication (4)
Crystal growth, controlled diffusion, determination of junction-depth and impurity profile, epitaxy, ion-implantation, oxidation, lithography, chemical vapor deposition, etching, process simulation and robust design for fabrication. *Prerequisite: ECE 103 with a grade of C– or better.* (S)

136L. Microelectronics Laboratory (4)
Laboratory fabrication of diodes and field effect transistors covering photolithography, oxidation, diffusion, thin film deposition, etching and evaluation of devices. (Lab fee: $35) *Prerequisite: ECE 103 with a grade of C– or better.* (F,S)

138L. Microstructuring Processing Technology Laboratory (4)
A laboratory course covering the concept and practice of microstructuring science and technology in fabricating devices relevant to sensors, lab-chips and related devices. (Lab fee: $40) *Prerequisite: upper-division standing for science and engineering students.* (W)

139. Semiconductor Device Design and Modeling (4)
Device physics of modern field effect transistors and bipolar transistors, including behavior of submicron structures. Relationship between structure and circuit models of transistors. CMOS and BiCMOS technologies. Emphasis on computer simulation of transistor operation and application in integrated circuits. *Prerequisites: ECE 135A-B with grades of C– or better.* (S)

145AL-BL-CL. Acoustics Laboratory (4-4-4)
Automated laboratory based on H-P GPIB controlled instruments. Software controlled data collection and analysis. Vibrations and waves in strings and bars of electromechanical systems and transducers. Transmissions, reflection, and scattering of sound waves in air and water. Aural and visual detection. *Prerequisite: ECE 107 with a grade of C– or better or consent of instructor.* (F-W-S)

146. Introduction to Magnetic Recording (4)
A laboratory introduction to the writing and reading of digital information in a disk drive. Basic magnetic recording measurements on state-of-art disk drives to evaluate signals, noise, erasure, and non-linearities that characterize this channel. Lectures on the recording process will allow comparison of measurements with basic voltage expressions. E/M FEM software utilized to study geometric effects on the record and play transducers. *Prerequisite: ECE 107 with a grade of C– or better.* (W)

153. Probability and Random Processes for Engineers (4)
Random processes. Stationary processes: correlation, power spectral density. Gaussian processes and linear transformation of Gaussian processes. Point processes. Random noise in linear systems. *Prerequisite: ECE 109 with a grade of C– or better.* (F,S)

154A. Communications Systems I (4)
Study of analog modulation systems including AM, SSB, DSB, VSB, FM, and PM. Performance analysis of both coherent and noncoherent receivers, including threshold effects in FM. *Prerequisite: ECE 101 and 153 with a grade of C– or better.* (F)

154B. Communications Systems II (4)
Design and performance analysis of digital modulation techniques, including probability of error results for PSK, DPSK, and FSK. Introduction to effects of intersymbol interference and fading. Detection and estimation theory, including optimal receiver design and maximum-likelihood parameter estimation. *Prerequisite: ECE 154A with a grade of C– or better.* (W)

154C. Communications Systems III (4)
Introduction to information theory and coding, including entropy, average mutual information, channel capacity, block codes and convolutional codes. *Prere-quisite: ECE 154B with a grade of C– or better.* (S)

155A. Digital Recording Systems (4)
This course will be concerned with modulation and coding techniques for digital recording channels. *Prerequisites: ECE 109 and 153 with grades of C– or better and concurrent registration in ECE 154A required. Department stamp required.* (F)

155B-C. Digital Recording Projects (4-4)
These courses will be concerned with modulation and coding techniques for digital recording channels. In winter and spring quarters, students will perform experiments and/or computer simulations. *Prerequisites: ECE 109 and 153 with grades of C– or better and concurrent registration in ECE 154B-C required. Department stamp required.* (W,S)

156. Sensor Networks (4)
Characteristics of chemical, biological, seismic, and other physical sensors; signal processing techniques supporting distributed detection of salient events; wireless communication and networking protocols supporting formation of robust sensor fabrics; current experience with low power, low cost sensor deployments. Undergraduate students must take a final exam; graduate students must write a term paper or complete a final project. Cross-listed with MAE 149 and SIO 238. *Prerequisite: upper-division standing and consent of instructor, or graduate student in science and engineering.*

158A. Data Networks I (4)
Layered network architectures, data link control protocols and multiple-access systems, performance analysis. Flow control; prevention of deadlock and throughput degradation. Routing, centralized and decentralized schemes, static dynamic algorithms. Shortest path and minimum average delay algorithms. Comparisons. *Prerequisite: ECE 109 with a grade of C– or better. ECE 159A recommended.* (W)

158B. Data Networks II (4)
Layered network architectures, data link control protocols and multiple-access systems, performance analysis. Flow control; prevention of deadlock and throughput degradation. Routing, centralized and decentralized schemes, static dynamic algorithms. Shortest path and minimum average delay algorithms. Comparisons. *Prerequisite: ECE 158A with a grade of C– or better.* (S)

159A. Queuing Systems: Fundamentals (4)
Analysis of single and multiserver queuing systems; queue size and waiting times. Modeling of telephone systems, interactive computer systems and the machine repair problems. *Prerequisite: ECE 109 with a grade of C– or better*. (F)

159B. Queuing Systems: Computer Systems and Data Networks (4)
M/G/1 queuing systems. Computer systems applications: priority scheduling; time-sharing scheduling. Open and closed queuing networks; modeling and performance of interactive computer systems. Elements of computer-communication networks: stability and delay analysis; optimal design issues. *Prerequisite: ECE 159A with a grade of C– or better.* (W)

161A. Introduction to Digital Signal Processing (4)
Review of discrete-time systems and signals, Discrete-Time Fourier Transform and its properties, the Fast Fourier Transform, design of Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filters, implementation of digital filters. *Prerequisite: ECE 101 and 109 with grades of C– or better.* (F,S)

161B. Digital Signal Processing I (4)
Sampling and quantization of baseband signals; A/D and D/A conversion, quantization noise, oversampling and noise shaping. Sampling of bandpass signals, undersampling downconversion, and Hilbert transforms. Coefficient quantization, roundoff noise, limit cycles and overflow oscillations. Insensitive filter structures, lattice and wave digital filters. Systems will be designed and tested with Matlab, implemented with DSP procesors and tested in the laboratory. (Lab fee: $15) *Prerequisite: ECE 161A with a grade of C– or better.* (W)

161C. Applications of Digital Signal Processing (4)
This course discusses several applications of DSP. Topics covered will include: speech analysis and coding; image and video compression and processing. A class project is required, algorithms simulated by MATLAB. (Lab fee: $15) *Prerequisite: ECE 161A with a grade of C- or better.* (S)

163. Electronic Circuits and Systems (4)
Analysis and design of analog circuits and systems. Feedback systems with applications to operational amplifier circuits. Stability, sensitivity, bandwidth, compensation. Design of active filters. Switched capacitor circuits. Phase-locked loops. Analog-to-digi-

tal and digital-to-analog conversion. (Lab fee: $10) *Prerequisites: ECE 101 and 102 with grades of C– or better.* (S)

164. Analog Integrated Circuit Design (4)
Design of linear and non-linear analog integrated circuits including operational amplifiers, voltage regulators, drivers, power stages, oscillators, and multipliers. Use of feedback and evaluation of noise performance. Parasitic effects of integrated circuit technology. Laboratory simulation and testing of circuits. *Prerequisite: ECE 102 with a grade of C– or better. ECE 163 recommended.* (F)

165. Digital Integrated Circuit Design (4)
VLSI digital systems. Circuit characterization, performance estimation, and optimization. Circuits for alternative logic styles and clocking schemes. Subsystems include ALUs, memory, processor arrays, and PLAs. Techniques for gate arrays, standard cell, and custom design. Design and simulation using CAD tools. (Students who have taken CSE 143 may not take ECE 165 for credit.) *Prerequisite: ECE 108 with a grade of C– or better.* (W)

166. Microwave Systems and Circuits (4)
Waves, distributed circuits, and scattering matrix-methods. Passive microwave elements. Impedance matching. Detection and frequency conversion using microwave diodes. Design of transistor amplifiers including noise performance. Circuits designs will be simulated by computer and tested in the laboratory. *Prerequisites: ECE 102 and 107 with grades of C– or better.* (S)

171A. Linear Control System Theory (4)
Stability of continous- and discrete-time single-input/single-output linear time-invariant control systems emphasizing frequency domain methods. Transient and steady-state behavior. Stability analysis by root locus, Bode, Nyquist, and Nichols plots. Compensator design. *Prerequisite: ECE 60B or ECE 53A-B or MAE 140 with a grade of C– or better.* (S)

171B. Linear Control System Theory (4)
Time-domain, state-variable formulation of the control problem for both discrete-time and continous-time linear systems. State-space realizations from transfer function system description. Internal and input-output stability, controllability/observability, minimal realizations, and pole-placement by full-state feedback. *Prerequisite: ECE 171A with a grade of C– or better.* (F)

172A. Introduction to Intelligent Systems: Robotics and Machine Intelligence (4)
This course will introduce basic concepts in machine perception. Topics covered will include: edge detection, segmentation, texture analysis, image registration, and compression. *Prerequisite: ECE 101 with a grade of C– or better, ECE 109 recommended.* (F)

173. Theory and Applications of Neural Networks and Fuzzy Logic (4)
Theory of fuzzy logic, reasoning and control; mathematical aspects of neural architectures for pattern classification, functional approximation, and adaptive estimation and control; theory of computer-assisted learning (supervised, unsupervised and hybrid); theory and practice of recurrent networks (stability, placement of equilibria); computer-aided design of fuzzy and neural systems, Bayes and minimax design. Pre*requisite: Math. 20F with a grade of C– or better.* (S)

174. Introduction to Linear and Nonlinear Optimization with Applications (4)
The linear least squares problem, including constrained and unconstrained quadratic optimization and the relationship to the geometry of linear transformations. Introduction to nonlinear optimization. Applications to signal processing, system identification, robotics, and circuit design. *Prerequisite: Math. 20F with a grade of C– or better.* (S)

175. Elements of Machine Intelligence: Pattern Recognition and Machine Learning (4)
Decision functions. Pattern classification by distance and likelihood functions; deterministic and statistical trainable pattern classifiers; feature selection; issues in machine learning. *Prerequisites: ECE 109 and ECE 174 with grades of C– or better.* (W)

181. Physical Optics and Fourier Optics (4)
Ray optics, wave optics, beam optics, Fourier optics, and electromagnetic optics. Ray transfer matrix, matrices of cascaded optics, numerical apertures of step and graded index fibers. Fresnel and Fraunhofer diffractions, interference of waves. Gaussian and Bessel beams, the ABCD law for transmissions through arbitrary optical systems. Spatial frequency, impulse response and transfer function of optical systems, Fourier transform and imaging properties of lenses, holography. Wave propagation in various (inhomogeneous, dispersive, anisotropic or nonlinear) media. *Prerequisites: ECE 103 and 107 with grades of C– or better.* (S)

182. Electromagnetic Optics, Guided-wave, and Fiber Optics (4)
Polarization optics: crystal optics, birefringence. Guided-wave optics: modes, losses, dispersion, coupling, switching. Fiber optics: step and graded index, single and multimode operation, attenuation, dispersion, fiber optic communications. Resonator optics. *Prerequisites: ECE 103 and 107 with grades of C– or better.* (F)

183. Optical Electronics (4)
Quantum electronics, interaction of light and matter in atomic systems, semiconductors. Laser amplifiers and laser systems. Photodetection. Electrooptics and acoustooptics, photonic switching. Fiber optic communication systems. Labs: semiconductor lasers, semiconductor photodetectors. (Lab fee: $35) *Prerequisites: ECE 103 and 107 with grades of C– or better.* (S)

184. Optical Information Processing and Holography (4)
Labs: optical holography, photorefractive effect, spatial filtering, computer generated holography. (Lab fee: $35) *Prerequisite: ECE 182 with a grade of C– or better.* (W)

185. Lasers and Modulators (4)
Labs: CO2 laser, HeNe laser, electrooptic modulation, acoustooptic modulation, spatial light modulators. (Lab fee: $35) *Prerequisite: ECE 183 with a grade of C– or better.* (S)

186L. Optical Information Systems (4)
Lab covering concepts in optical data systems including free-space communications, remote sensing and wavelength-multiplexed optical fiber transmission. (Lab fee: $35.00) *Prerequisites: ECE 181 and 182 or 183 with grades of C– or better, or consent of instructor.*

187. Introduction to Biomedical Imaging and Sensing (4)
Image processing fundamentals: imaging theory, image processing, pattern recognition; digital radiography, computerized tomography, nuclear medicine imaging, nuclear magnetic resonance imaging, ultrasound imaging, microscopy imaging. *Prerequisite: Math. 20A-B-F, 20C or 21C, 20D or 21D, Phys. 2A-D, ECE 101 (may be taken concurrently) with grades of C– or better.* (F)

191. Engineering Group Design Project (4)
Groups of students work to design, build, demonstrate, and document an engineering project. All students give weekly progress reports of their tasks and contribute a section to the final project report. *Prerequisites: Completion of all of the breadth courses and one depth course.* (W)

192. Engineering Design (4)
Students complete a project comprising at least 50 percent or more engineering design to satisfy the following features: student creativity, open-ended formulation of a problem statement/specifications, consideration of alternative solutions/realistic constraints. Written final report required. *Prerequisites: Students enrolling in this course must have completed all of the breadth courses and one depth course. The department stamp is required to enroll in ECE 192.* (Specifications and enrollment forms are available in the undergraduate office.)

193H. Honors Project (4-8)
An advanced reading or research project performed under the direction of an ECE faculty member. Must contain enough design to satisfy the ECE program's four-unit design requirement. Must be taken for a letter grade. May extend over two quarters with a grade assigned at completion for both quarters. *Prerequisite: admission to the ECE departmental honors program.*

195. Teaching (2 or 4)
Teaching and tutorial activities associated with courses and seminars. Not more than four units of ECE 195 may be used for satisfying graduation requirements. (P/NP grades only.) *Prerequisite: consent of the department chair.*

197. Field Study in Electrical and Computer Engineering (4, 8, 12, or 16)
Directed study and research at laboratories and observatories away from the campus. (P/NP grades only.) *Prerequisites: consent of instructor and approval of the department.*

198. Directed Group Study (2 or 4)
Topics in electrical and computer engineering whose study involves reading and discussion by a small group of students under direction of a faculty member. (P/NP grades only.) *Prerequisite: consent of instructor.*

199. Independent Study for Undergraduates (2 or 4)
Independent reading or research by special arrangement with a faculty member. (P/NP grades only.) *Prerequisite: consent of instructor.*

GRADUATE

200. Research Conference (2)
Group discussion of research activities and progress of group members. (S/U grades only.) *Prerequisite: consent of instructor.* (F,W,S)

210. Information Systems in Manufacturing (4)
Basic problem solving and search techniques. Knowledge based and expert systems. Planning and decision support systems. Fuzzy logic and neural nets. Topics covered will include data models, query processing, distributed systems, enterprise computing and intelligent agents, fuzzy logic, neural nets. *Prerequisite: basic engineering and introduction to computers.* (W)

211. Manufacturing Engineering Seminar and Laboratory (2)
Combination of seminars, laboratory activities, and field trips. Seminars by top manufacturing engineers, managers, and student interns. Visits to manufacturing facilities. Techniques in accessing international technical and patent databases. *Prerequisite: none..*

222A-B-C. Applied Electromagnetic Theory (4)
Electrostatics and dielectric materials. Uniqueness, reciprocity, and Poynting theorems. Solutions to Maxwell's equations in rectangular, cylindrical, and spherical coordinates. Waves in isotropic and anisotropic media, transmission lines, wave-guides, optical fibers, and resonant structures. Radiation, propagation, and scattering problems. Scattering matrices, microwave circuits, and antennas. *Prerequisites: ECE 107, 123, 124 or equivalent.* (F,W,S)

223. Nonlinear Waves with Dispersion (4)
This course explores nonlinear wave phenomena developing in a dispersive media. We shall investigate such phenomena as formation of solitons, collisionless shocks, nonlinear self focusing, and wave collapse. Analysis will be based on the solution of the main equations of nonlinear physics—Kortveg de Vries (KDV), Burgers, and nonlinear Schrodinger equation. Possible areas of application include nonlinear optics, fluid dynamics, plasma and space physics. *Prerequisite: ECE 222A or PHYS 203A or equivalent*. (S)

230A. Solid State Electronics (4)
This course is designed to provide a general background in solid state electronic materials and devices. Course content emphasizes the fundamental and current issues of semiconductor physics related to the ECE solid state electronics sequences. *Prerequisites: fundamentals of quantum mechanics, ECE 135A-B, or equivalent.* (F)

230B. Solid State Electronics (4)
Physics of solid-state electronic devices, including p-n diodes, Schottky diodes, field-effect transistors, bipolar transistors, pnpn structures. Computer simulation of devices, scaling characteristics, high frequency performance, and circuit models. *Prerequisite: ECE 230A.* (W)

230C. Solid State Electronics (4)
This course is designed to provide a treatise of semiconductor devices based on solid state phenomena. Band structures carrier scattering and recombination processes and their influence on transport properties will be emphasized. *Prerequisite: ECE 230A or equivalent.* (S)

232. The Field Effect and Field Effect Transistors (4)
Physics of the field effect of elemental and III-V compound semiconductors related to the technology and characteristics of Schottky barrier gate, insulated gate, and junction gate field effect transistors. *Prerequisite: consent of instructor.* (S)

234A. Imperfections in Solids (4)
Point, line, and planar defects in crystalline solids, including vacancies, self-interstitials, solute atoms, dislocation interactions, stacking faults, grain boundaries, and their effects on the properties of solids. Hardening by localized obstacles, precipitates, and dispersoids. Cross-listed with MAE 272 and MATS 205A. *Prere-quisite: consent of instructor.* (F)

234B. Advanced Study of Defects in Solids (4)
Advanced topics in dislocation theory and dislocation dynamics. Defects and defects interactions. Atomistic and subatomistic effects. Physical models based on microscopic considerations. Cross-listed with MATS 205B. *Prerequisite: ECE 234A or consent of instructor.* (W)

235. Nanometer-Scale VLSI Devices (4)
This course covers modern research topics in sub-100 nm scale, state-of-the-art silicon VLSI devices. Starting with the fundamentals of CMOS scaling to nanometer dimensions, various advanced device and circuit concepts, including RF CMOS, low power CMOS, silicon memory, silicon-on-insulator, SiGe bipolar, strained silicon MOSFET's, etc. will be taught. The physics of near-ballistic transport in an ultimately scaled 10 nm MOSFET will be discussed in light of the recently developed scattering theory. *Prerequisite: graduate standing*. (F)

236A. Semiconductor Heterostructure Materials (4)
This course covers the growth, characterization, and heterojunction properties of III-IV compound semiconductors and group-IV semiconductor heterostructures for the subsequent courses on electronic and photonic device applications. Topics include epitaxial growth techniques, electrical properties of heterojunctions, transport and optical properties of quantum wells and superlattices. *Prerequisites: ECE 230A-B-C or consent of instructor.* (W)

236B. Optical Processes in Semiconductors (4)
Absorption and emission of radiation in semiconductors. Radiative transition and nonradiative recombination. Ultra-fast optical phenomena. Laser and photodetector devices will be emphasized. *Prerequisites: ECE 230A and 230C or equivalent.* (W)

236C. Heterojunction Field Effect Transistors (4)
Device physics and applications of isotype and anisotype heterojunctions and quantum wells, including band-edge discontinuities, band bending and space charge layers at heterojunction interfaces, charge transport normal and parallel to such interfaces, two-dimensional electron gas structures, modulation doping, heterojunction and insulated gate field effect transistors. *Prerequisite: consent of instructor.* (S)

236D. Heterojunction Bipolar Transistors (4)
Current flow and charge storage in bipolar transistors. Use of heterojunctions to improve bipolar structures. Transient electron velocity overshoot. Simulation of device characteristics. Circuit models of HBTs. Requirements for high-speed circuit applications. Elements of bipolar process technology, with emphasis on III-V materials. *Prerequisite: consent of instructor.* (F)

237. Modern Materials Analysis (4)
Analysis of the near surface of materials via ion, electron, and x-ray spectroscopes. Topics to be covered include particle solid interactions. Rutherford backscattering, secondary ion mass spectroscopy, electron energy loss spectroscopy, particle induced x-ray emission, Auger electron spectroscopy, extended z-ray absorption, fine structure and channeling. *Prerequisite: consent of instructor.* (F)

238A. Thermodynamics of Solids (4)
The thermodynamics and statistical mechanics of solids. Basic concepts, equilibrium properties of alloy systems, thermodynamic information from phase diagrams, surfaces and interfaces, crystalline defects. Multiple listed with Materials Science 201A. *Prerequisite: consent of instructor.* (F)

238B. Solid State Diffusion and Reaction Kinetics (4)
Thermally activated processes. Boltzman factor, homogeneous and heterogeneous reactions, solid state diffusion, Fick's law, diffusion mechanisms, Kirkendall effects, Boltzmann-Manato analysis, high diffusivity paths. Multiple listed with Materials Science 201B. *Prerequisite: ECE 238A.* (W)

240A. Lasers and Optics (4)
Fresnel and Fraunhofer diffraction theory. Optical resonators, interferometry. Gaussian beam propagation and transformation. Laser oscillation and amplification, Q-switching and mode locking of lasers, some specific laser systems. *Prerequisites: ECE 123, 124 or equivalent; introductory quantum mechanics or ECE183.* (F)

240B. Optical Information Processing (4)
Space-bandwidth product, superresolution, space-variant optical system, partial coherence, image processing with coherent and incoherent light, processing with feedback, real-time light modulators for hybrid processing, nonlinear processing. Optical computing and other applications. *Prerequisite: ECE 182 or equivalent*. (W)

240C. Optical Modulation and Detection (4)
Propagation of waves and rays in anisotropic media. Electro-optical switching and modulation. Acousto-optical deflection and modulation. Detection theory. Heterodyne detection, incoherent and coherent detection. *Prerequisites: ECE 181,183 or equivalent.* (S)

241A. Nonlinear Optics (4)
Second harmonic generation (color conversion), parametric amplification and oscillation, photorefractive effects and four-wave mixing, optical bistability; applications. *Prerequisites: ECE 240A, C, or consent of instructor.* (F)

241B. Optical Devices for Computing. (4)
Application of electro-optic, magneto-optic, acousto-optic, and electro-absorption effects to the design of photonic devices with emphasis on spatial light modulation and optical storage techniques. *Prerequisites: ECE 240A, C, or consent of instructor.* (F)

241C. Holographic Optical Elements (4)
Fresnel, Fraunhofer, and Fourier holography. Analysis of thin and volume holograms, reflection and transmission holograms, color and polarization holograms. Optically recorded and computer-generated holography. Applications to information storage, optical interconnects, 2-D and 3-D display, pattern recognition, and image processing. *Prerequisite: ECE 182 or equivalent, or consent of instructor.* (W)

241AL. Lasers and Holography Laboratory (2)
Laser resonator design, construction, alignment, characterizations. Operation and evaluation of molecular, gas, liquid dye, semiconductor lasers. Spatial and temporal coherance measurements. Design and fabrication of transmission, reflection, bleached, color, multiple exposure holograms. *Prerequisites: ECE 181,182,183 or consent of instructor. (This course is cojoint with ECE 184. Graduate students will choose 50 percent of the experiments and receive two units of credit.)* (F)

241BL. Optical Signal Processing Laboratory (2)
Construction and characterization of Fourier/Fresnel transform, coherent/incoherent, imaging-processing systems. Design, coding, fabrication of spatial filters, computer-generated holograms. Experiments in non-linear photorefractive phenomena and image-processing applications. Construction of vector-matrix multipliers. Optical systems design using Code-V. *Prerequisites: ECE 181, 182, 183, or consent of instructor. (This course is cojoint with ECE 185. Graduate stduents will choose 50 percent of the experiments and receive two units of credit.)* (W)

241CL. Optoelectronics and Communications laboratory (2)
Operation and characterization of electro-optic, acousto-optic modulators. Polarization manipulation techniques. Heterodyne detection schemes. Parametrization of P-I-N and avalanche detectors, LED sources. Evaluation of optical fiber, thin film waveguide properties. Characterization of Hughes LCLV spatial light modulator. *Prerequisites: ECE 181, 182, 183, or consent of instructor.*

242A. Nanophotonics (4)
Photonic properties of artificially engineered inhomogenerous nanoscale composite materials (e.g., dielectrics, semiconductors, metalo-dielectrics); nanophotonic devices and components; resonant nanostructures and resonant photonic devices and circuits; mear field localization effects and applications; nanophotonics for on-chip integration; overview of fabrication and characterizations techniques for nanophotonics. *Prerequisites: ECE 240A-B-C.* (S)

243B. Optical Fiber Communication (4)
Optical fibers, waveguides, laser communication system. Modulation and demodulation; detection processes and communication-receivers. *Prerequisites: ECE 240A or 240B or 240C or equivalent.* (W)

244A. Statistical Optics (4)
Introduction to statistical phenomena in optics including first order properties of light waves generated from various sources. Coherence of optical waves, high-order coherence. Partial coherence and its effects on imaging systems. Imaging in presence of randomly inhomogeneous medium. Limits in photelectric detection of light. *Prerequisite: ECE 240A-B or consent of instructor.* (F)

244B. Quantum Electronics of Femtosecond Optical Pulses (4)
Femtosecond optical pulses in linear dispersive media. Self-action of optical pulses. Parametric interaction of optical pulses. Self- and cross-phase modulation. Fast phase control, compression and shaping of optical pulses. Optical solitons. Applications of femtosecond optical pulses. *Prerequisite: ECE 240A-B-C or consent of instructor.* (W)

245A. Advanced Acoustics I (4)
Boundary value problems in vibrating systems, wave propagation in strings, bars, and plates. Fundamentals of acoustical transducers. *Prerequisite: concurrent registration in ECE 145AL recommended.* (F)

245B. Advanced Acoustics II (4)
Theory of radiation transmission and scattering of sound with special application to ocean acoustics. *Prerequisite: ECE 245A or consent of instructor. Concurrent registration in ECE 145BL recommended.* (W)

245C. Advanced Acoustics III (4)
Signal processing in underwater acoustics. Theory and hardwave embodiments. *Prerequisite: ECE 245B or consent of instructor. Concurrent registration in ECE 145CL recommended.* (S)

246A. Materials for Magnetic Recording (4)
Properties of magnetic materials utilized as magnetic recording media and heads; magnetic structure of oxides and metals; fine particle magnetism: micromagnetic analysis; hysteresis and reversal mechanisms of hard materials; dynamic processes and domain patterns of soft materials; thermal fluctuations; multilayer phenomena: giant magnetoresistance. *Prerequisites: undergraduate electromagnetism and solid state physics or consent of instructor.* (alternate years)

246B. Analysis of the Magnetic Recording Process (4)
In-depth analysis of the magnetic recording process. Magnetic fields and Fourier transforms of fields and magnetized media and heads; playback process for single and multiple transitions. Reciprocity theorem for inductive and magnetoresistive heads; record process modeling; interferences and nonlinearities; medium noise mechanisms and correlations; signal to noise ratios. *Prerequisites: undergraduate electromagnetic theory and mathematical methods or consent of instructor.* (alternate years)

246C. Magnetic Recording Laboratory (4)
Basic measurements in magnetic recording. Fields and Fourier transforms of head structures using resistance paper measurements and computer analysis; inductance and B-H loop measurements of recording heads and core materials; recording system calibration and magnetization pattern investigation utilizing spectral measurements (FFT). *Prerequisites: ECE 246B and laboratory experience.* (alternate years)

247A. Advanced BioPhotonics (4)
Basic physics and chemistry for the interaction of photons with matter, including both biological and synthetic materials; use of photonic radiation pressure for manipulation of objects and materials; advanced optoelectronic detection systems, devices and methods, including time resolved fluorescent and chemiluminescent methods, fluorescent energy transfer (FRET) techniques, quantum dots, and near-field optical techniques; underlying mechanisms of the light sensitive biological systems, including chloroplasts for photosynthetic energy conversion and the basis of vision processes. Cross-listed with BENG 247A. *Prerequisite: graduate standing*. (F)

247B. BioElectronics (4)
Topics to be covered will include photolithographic techniques for high-density DNA microarray production, incorporation of CMOS control into electronic DNA microarrays, direct electronic detection technology used in microarrays and biosensor devices, and focus on problems related to making highly integrated devices (lab-on-a-chip, in-vivo biosensors, etc.) from heterogeneous materials and components. Cross-listed with BENG 247B. *Prerequisite: graduate standing.* (W)

247C. BioNanotechnology (4)
Topics include: nanosensors and nanodevices for both clinical diagnostics and biowarfare (bioterror) agent detection; nanostructures for drug delivery; nanoarrays and nanodevices; use of nanoanalytical devices and systems; methods and techniques for modification or functionalization of nanoparticles and nanostructures with biological molecules; nanostructural aspects of fuel cells and bio-fuel cells; potential use of DNA and other biomolecules for computing and ultra-high-density data storage. Cross-listed with BENG 247C. *Prerequisite: graduate standing.* (S)

250. Random Processes (4)
Random variables, probability distributions and densities, characteristic functions. Convergence in probability and in quadratic mean, Stochastic processes, stationarity. Processes with orthogonal and independent increments. Power spectrum and power spectral density. Stochastic integrals and derivatives. Spectral representation of wide sense stationary processes, harmonizable processes, moving average representations. *Prerequisite: ECE 153 or equivalent or consent of instructor.* (F)

251AN. Digital Signal Processing I (4)
Discrete random signals; conventional (FFT based) spectral estimation. Coherence and transfer function estimation; model-based spectral estimation; linear prediction and AR modeling. Levinson-Durbin algorithm and lattice filters, minimum variance spectrum estimation. *Prerequisites: ECE 153 in addition to either ECE 161 or 161A, or consent of instructor.* (W)

251BN. Digital Signal Processing II (4)
Adaptive filter theory, estimation errors for recursive least squares and gradient algorithms, convergence and tracking analysis of LMS, RLS, and Kalman filtering algorithms, comparative performance of Weiner and adaptive filters, transversal and lattice filter implementations, performance analysis for equalization, noise cancelling, and linear prediction applications. *Prerequisite: ECE 251AN.* (S)

251CN. Filter Banks and Wavelets (4)
Fundamentals of multirate systems (noble identities, polyphase representations), maximally decimated filter banks (QMF filters for 2-channels, M-channel perfect reconstruction systems), paraunitary perfect reconstruction filter banks, the wavelet transform (multiresolution, discrete wavelet transform, filter banks and wavelet). *Prerequisite: ECE 161B or equivalent.* (F)

251DN. Array Processing (4)
The coherent processing of data collected from sensors distributed in space for signal enhancement and noise rejection purposes or wavefield directionality estimation. Conventional and adaptive beamforming. Matched field processing. Sparse array design and processing techniques. Applications to acoustics, geophysics, and electromagnetics. *Prerequisite: 251AN, ECE 161 or 151A (ECE 161, 162A-B series recently renumbered to ECE 161A-B-C), or consent of instructor.* (F)

252A. Speech Compression (4)
Speech signals, production and perception, compression theory, high rate compression using waveform coding (PCM, DPCM, ADPCM, . .), DSP tools for low rate coding, LPC vocoders, sinusoidal tranform coding, multi-band coding, medium rate coding using code excited linear prediction (CELP). *Prerequisite: ECE 161A or 161.* (W)

252B. Speech Recognition (4)
Signal analysis methods for recognition, dynamic time warping, isolated word recognition, hidden markov models, connectedword, and continuous speech recognition. *Prerequisites: ECE 109, ECE 262A.* (S)

253A. Fundamentals of Digital Image Processing (4)
Image quantization and sampling, image transforms, image enhancement, image compression. *Prerequisites: ECE 109, 153, ECE 161 or ECE 161A.* (W)

253B. Digital Image Analysis (4)
Image morphology, edge detection, scene segmentation, texture analysis, registration and fusion, feature analysis, time-varying images. *Prerequisite: ECE 253A or consent of instructor.* (S)

254. Detection Theory (4)
Hypothesis testing, detection of signals in white and colored Gaussian noise; Karhunen-Loève expansion, estimation of signal parameters, maximum-likelihood detection; resolution of signals; detection and estimation of stochastic signals; applications to radar, communications, and optics. *Prerequisite: ECE 153.* (F)

255AN. Information Theory (4)
Introduction to basic concepts, source coding theorems, capacity, noisy-channel coding theorem. *Prerequisite: ECE 154A-B-C or consent of instructor.* (F)

255BN/CN. Source Coding I, II (4/4)
Theory and practice of lossy source coding, vector quantization, predictive and differential encoding, universal coding, source-channel coding, asymptotic theory, speech and image applications. *Prerequisite: ECE 250 and 259A or 259AN, or consent of instructor.* (W,S)

256A-B. Time Series Analysis and Applications (4-4)
Stationary processes; spectral representation; linear transformation. Recursive and nonrecursive prediction and filtering; Wiener-Hopf and Kalman-Bucy filters. Series expansions and applications. Time series analysis; probability density, covariance and spectral estimation. Inference from sampled-data, sampling theorems; equally and non-equally spaced data, applications to detection and estimation problem. *Prerequisite: ECE 153.* (F,W)

257A. Multiuser Communication Systems (4)
M/G/1, G1/M/1 queues, imbedded chains. Ergodic theory of Markov chains, classification, ergodic theorems. Multiple access systems, random access protocols, capacity, stability, delay and control, reservation and hybrid schemes. *Prerequisites: ECE 153 and 159A, or equivalent. Note: ECE 159A is an integral part of this course and should be taken in the fall quarter.* (W)

257B. Principles of Wireless Networks (4)
This course will focus on the principles, architectures, and analytical methodologies for design of multi-user wireless networks. Topics to be covered include cellular approaches, call processing, digital modulation, adaptive arrays, broadband networks, and wireless packet access for multimedia service. *Prerequisites: ECE 159B and 154B.* (S)

258A-B. Digital Communication (4-4)
Digital communication theory including performance of various modulation techniques, effects of intersymbol interference, adaptive equalization, spread spectrum communication. *Prerequisites: ECE 154A-B-C and ECE 254 or consent of instructor.* (W,S)

259AN. Algebraic Coding (4)
Fundamentals of block codes, introduction to groups, rings and finite fields, nonbinary codes, cyclic codes such as BCH and RS codes, decoding algorithms, applications. *Prerequisite: consent of instructor.* (F)

259BN. Trellis-Coded Modulation (4)
Coding theory developed from the viewpoint of digital communications engineering, information theoretic limits for basic channel models, convolutional codes, maximum-likelihood decoding, Ungerboeck codes, codes based on lattices and cosets, rotational invariance, performance evaluation, applications of modem design. *Prerequisites: ECE 154A-B-C, ECE 259A or 259AN, or consent of instructor.* (W)

259CN. Advanced Coding and Modulation for Digital Communications (4)
Advanced coding and modulation techniques for bandwidth-efficient data transmission and recording; constellation shaping by regions, Voronoi constellations, shell mapping, coding for intersymbol-interference channels, precoding methods, multilevel coding; coding for fading channels, applications to wireline and wireless communications, digital recording. *Prerequisites: ECE 259A-B or 259AN-BN.* (S)

260A. VLSI Digital System Algorithms and Architectures (4)
Custom and semicustom VLSI design from the system designer's perspective. VLSI system algorithms, parallel processing architectures and interconnection networks, and design mapping methodologies will be emphasized. VLSI computer-aided design (CAD) tools will be introduced. Knowledge of basic semiconductor electronics and digital design is assumed. *Prerequisites: undergraduate-level semiconductor electronics and digital system design; ECE 165 or equivalent or consent of instructor.* (F)

260B. VLSI Integrated Circuits and Systems Design (4)
Computer arithmetic, control and memory structures for VLSI implementations at logic, circuit, and layout level. Computer-aided design and performance simulations, actual design projects for teams of two to three students per team. Layout done on CAD workstations for project IC chip fabrication. Design projects will be reviewed in class presentation. *Prerequisite: ECE 260A.* (W)

260C. VLSI Advanced Topics (4)
Advanced topics seminar with issues from system theory, to new technologies, to alternative design methodologies will be subject for review. Class discussion, participation and presentations of projects and special topics assignments will be emphasized. The testing results of fabricated IC chips from other VLSI design classes will be presented in class and in a final report. *Prerequisite: ECE 260B.* (S)

261A. Design of Analog and Digital GaAs Integrated Circuits I (4)
Introduction to analytical and computer-aided design (CAD) techniques for microwave integrated circuits. Design of active two-ports using scattering parameters. Monolithic realization of low-noise amplifiers using GaAs FETs and HEMTs. Design of monolithic distributed amplifiers. Design of monolithic power amplifiers and mixers. *Prerequisite: consent of instructor.* (W)

261B. Design of Analog and Digital GaAs Integrated Circuits (4)
Introduction to GaAs digital integrated circuits (IC). Design of simple digital GaAs ICs using DCFL. Design of digital building blocks for complex multipliers, FET butterfly chips, DDS, and oversampled A/D converters. *Prerequisite: consent of instructor.* (S)

264A. CMOS Analog Integrated Circuits and Systems I (4)
Frequency response of the basic CMOS gain stage and current mirror configurations. Advanced feedback and stability analysis; compensation techniques. High-Performance CMOS amplifier topologies. Switched capacitor circuits. Analysis of noise and distortion. *Prerequisites: ECE 164 and 153 or equivalent courses.* (W)

264B. CMOS Analog Integrated Circuits and Systems II (4)
Continuous-time filters: synthesis techniques and CMOS circuit topologies. Switched-capacitor filters: synthesis techniques and CMOS circuit topologies. Overview of CMOS samplers, data converters, mixers, modulators, oscillators, and PLLs. *Prerequisites: ECE 264A and 251A or 251AN.* (S)

264C. CMOS Analog Integrated Circuits and Systems III (4)
Integrated CMOS analog/digital systems: Analog to digital and digital to analog converters, Nyquist versus oversampling, linearity, jitter, randomization, calibration, speed versus resolution, pipeline, folding, interpolation, averaging. *Prerequisites: ECE 163 and 164.* (W)

264D. CMOS Analog Integrated Circuits and Systems IV (4)
PLL: Phase noise effect, VCO, phase detector, charge pump, integer/fractional-N frequency synthesizer, clock and data recovery, decision feedback. Filter: Continuous-time filter, I-Q complex filter, raised-cosine, Gaussian, delay, zero equalizers. *Prerequisites: ECE 163 and 164.* (S)

265A. Communication Circuit Design I (4)
Introduction to noise and linearity concepts. System budgeting for optimum dynamic range. Frequency plan tradeoffs. Linearity analysis techniques. Down-conversion and up-conversion techniques. Modulation and de-modulation. Microwave and RF system design communications. Current research topics in the field. *Prerequisites: consent of instructor.* (F)

265B. Communication Circuit Design II (4)
Radio frequency integrated circuits: impedance matching concepts, low-noise amplifiers, AGCs. Mixers, filters. Comparison between BJT, CMOS and GaAs technologies for radio frequency and microwave applications. Device modeling for radio frequency applications. Design tradeoffs of linearity, noise, power dissipation, and dynamic range. Current research topics in the field. *Prerequisites: ECE 164 and 265A or consent of instructor.* (W)

270A-B-C. Neurocomputing (4-4-4)
Neurocomputing is the study of biological information processing from an artificial intelligence engineering perspective. This three-quarter sequence covers neural network structures for arbitrary object (perceptual, motor, thought process, abstraction, etc.) representation, learning of pairwise object attribute descriptor antecedent support relationships, the general mechanism of thought, and situationally responsive generation of movements and thoughts. Experimental homework assignments strongly reinforce the fundamental concepts and provide experience with myriad associated technical issues. *Prerequisite: graduate standing, an understanding of mathematics through basic linear algebra and probability, or consent of instructor.* (F,W,S)

271A. Statistical Learning I (4)
Bayesian decision theory; parameter estimation; maximum likelihood; the bias-variance trade-off; Bayesian estimation; the predictive distribution; conjugate and noninformative priors; dimensionality and dimensionality reduction; principal component analysis; Fisher's linear discriminant analysis; density estimation; parametric vs. kernel-based methods; expectation-maximization; applications. *Prerequisite: ECE 109.* (F)

271B. Statistical Learning II (4)
Linear discriminants; the Perceptron; the margin and large margin classifiers; learning theory; empirical vs. structural risk minimization; the VC dimension; kernel functions; reproducing kernel Hilbert spaces; regularization theory; Lagrangian optimization; duality theory; the support vector machine; boosting; Gaussian processes; applications. *Prerequisites: ECE 109, 271A.* (F)

272A. Stochastic Processes in Dynamic Systems (4)
(Not offered 2001/2002.) Diffusion equations, linear and nonlinear estimation and detection, random fields, optimization of stochastic dynamic systems, applications of stochastic optimization to problems. *Prerequisites: ECE 250.* (W,S)

275A. Parameter Estimation I (4)
Linear last squares (batch, recursive, total, sparse, psuedoinverse, QR, SVD); statistical figures of merit (bias, consistency, Cramer-Rao lower-bound, efficiency); maximum likelihood estimation (MLE); sufficient statistics; algorithms for computing the MLE including the expectation maximation (EM) algorithm. The problem of missing information; the problem of outliers. *Prerequisites: ECE 109 and ECE 153 with grades of C– or better.* (F)

275B. Parameter Estimation II (4)
The Bayesian framework and the use of statistical priors; sufficient statistics and reproducing probability distributions; minimum mean square estimation (MSE); linear minimum mean square estimation; maximum a posteriori (MAP) estimation; minimax estimation; Kalman filter and extended Kalman filter (EKF) Baum-Welsh algorithm; Viterbi algorithm. Applications to identifying the parameters and states of hidden Markov models (HMMs) including ARMA, state-space, and finite-state dynamical systems. Applications to parametric and non-parametric density estimation. *Prerequisites: ECE 153 and ECE 275A with grades of C– or better.* (W)

276A-B. Robot Kinematics, Dynamics, and Control (4-4)
Kinematics of rigid bodies and serial-chain manipulators. The forward and inverse kinematics problem. Sufficient conditions for exact solvability of the inverse kinematics problem. Joint-space versus tank-space control. Path/trajectory generation. Newton-Euler and Lagrangian formulation of manipulatory dynamics. Manipulability measures. Redundancy resolution by subtask functional optimization and side-constraint satisfaction. Pseudo-inverse kinematic control of redundant manipulators. PID and feedback-linearizing trajectory and force control. Issues in path planning and compliant assembly. *Prerequisites: ECE 171A-B, ECE 174 must be completed with grades of C– or better. (ECE 174 may be concurrent.)* (W-S)

280. Special Topics in Electronic Devices and Materials (4)
A course to be given at the discretion of the faculty at which topics of interest in electronic devices and materials will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. *Prerequisite: consent of instructor.*

282. Special Topics in Optoelectronics (4)
A course to be given at the discretion of the faculty at which topics of interest in optoelectronic materials, devices, systems, and applications will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit several times. *Prerequisite: consent of instructor.*

283. Special Topics in Electronic Circuits and Systems (4)
A course to be given at the discretion of the faculty at which topics of interest in electronic circuits and systems will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. *Prerequisite: consent of instructor.*

284. Special Topics in Computer Engineering (4)
A course to be given at the discretion of the faculty at which topics of interest in computer engineering will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. *Prerequisite: consent of instructor.*

285. Special Topics in Robotics and Control Systems (4)
A course to be given at the discretion of the faculty at which topics of interest in robotics and control systems will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. *Prerequisite: consent of instructor.*

287A,B. Special Topics in Communication Theory and Systems (4)
A course to be given at the discretion of the faculty at which topics of interest in information science will be presented by visiting or resident faculty members. It will not be repeated so it may be taken for credit more than once. *Prerequisite: consent of instructor*.

288. Special Topics in Applied Physics (4)
Topics of interest in applied physics. Topics will vary from quarter to quarter. May be repeated for credit not more than three times. *Prerequisite: consent of instructor.*

290. Graduate Seminar on Current ECE Research (2)
Weekly discussion of current research conducted in the Department of Electrical and Computer Engineering by the faculty members involved in the research projects.

291. Industry Sponsored Engineering Design Project (4)
One or two students as a group design, build, and demonstrate an engineering project that is sponsored by local industry. All students give a weekly progress report on their tasks and write a final report. The projects originate from the actual needs of industry in the general area of electrical and computer engineering. This course may count towards the fulfillment of the MEng degree. Individual final exam and final presentation. *Prerequisite: ECE 230 or 240 or 251 or 253 or 258 or equivalent.*

293. Graduate Seminar in Communication Theory and Systems (2)
Weekly discussion of current research literature.

294. Graduate Seminar in Applied Solid State Physics (2)
Research topics in applied solid state physics and quantum electronics.

296. Graduate Seminar in Optical Signal Processing (2)
Research topics of current interest in holography.

298. Independent Study (1-16)
Open to properly qualified graduate students who wish to pursue a problem through advanced study under the direction of a member of the staff. (S/U grades only.) *Prerequisite: consent of instructor.*

299. Research (1-16)
(S/U grade only.)

501. Teaching (1-4)
Teaching and tutorial activities associated with courses and seminars. Not required for candidates for the Ph.D. degree. Number of units for credit depends on number of hours devoted to class or section assistance. (S/U grade only.) *Prerequisite: consent of department chair.∆1*