ELECTRICAL ENGINEERING

Courses offered by the Department of Electrical Engineering are listed under the subject code EE (https://explorecourses.stanford.edu/search?view=catalog&academicYear=&q=EE&filter-departmentcode-EE=on&filter-coursestatus-Active=on&filter-term-Autumn=on&filter-term-Winter=on&filter-term-Spring=on&filter-term-Summer=on&page=0) on the *Stanford Bulletin's* ExploreCourses web site.

Mission of the Undergraduate Program in Electrical Engineering

The mission of the undergraduate program of the Department of Electrical Engineering is to augment the liberal education expected of all Stanford undergraduates, to impart basic understanding of electrical engineering and to develop skills in the design and building of systems that directly impact societal needs.

The program includes a balanced foundation in the physical sciences, mathematics and computing; core courses in electronics, information systems and digital systems; and develops specific skills in the analysis and design of systems. Students in the major have broad flexibility to select from many specialization areas beyond the core, including areas in electronics, optics, information systems and hardware and software systems as well as application-oriented cross-cuts in bio-instrumentation and bio-imaging, energy and environment and music.

The program prepares students for a broad range of careers—both industrial and government—as well as for professional and academic graduate education.

Learning Outcomes (Undergraduate)

The department expects undergraduate majors in the program to be able to demonstrate the following learning outcomes. These learning outcomes are used in evaluating students and the department's undergraduate program. The educational objectives of the program are:

1. Technical knowledge—provide a knowledge of electrical engineering principles along with the required supporting knowledge of computing, engineering fundamentals, mathematics, and science. The program must include depth in at least one specialty area, currently including bio-electronics and bio-imaging; circuits and devices; computer hardware; computer software; music; signal processing, communication and controls; and photonics, solid state and electromagnetics; and energy and environment.
2. Laboratory and design skills—develop the basic skills needed to perform and design experimental projects. Develop the ability to formulate problems and projects and to plan a process for solution, taking advantage of diverse technical knowledge and skills.
3. Communications skills—develop the ability to organize and present information and to write and speak effective English.
4. Preparation for further study—provide sufficient breadth and depth for successful subsequent graduate study, postgraduate study, or lifelong learning programs.
5. Preparation for the profession—provide an appreciation for the broad spectrum of issues arising in professional practice, including economics, ethics, leadership, professional organizations, safety, service, and teamwork.

Learning Outcomes (Graduate)

The purpose of the master's program is to provide students with the knowledge and skills necessary for a professional career or doctoral studies. This is done through course work providing specialization in one area of Electrical Engineering and breadth in several other areas. Areas of specialization include bio-electrical engineering; hardware; software; control and system engineering; communication systems; dynamic systems and optimization; circuits; devices, sensors and technology; fields, waves and radioscience; image systems; lasers, optoelectronics and quantum electronics; network systems; signal processing; solid state materials and devices.

The Ph.D. is conferred upon candidates who have demonstrated substantial scholarship and the ability to conduct independent research. Through course work and guided research, the program prepares students to make original contributions in Electrical Engineering and related fields.

Graduate Programs in Electrical Engineering

University regulations governing the M.S. and Ph.D. degrees are described in the "Graduate Degrees" section of this bulletin.

The profession of electrical engineering demands a strong foundation in physical science and mathematics, a broad knowledge of engineering techniques, and an understanding of the relationship between technology and society. Curricula at Stanford are planned to offer the breadth of education and depth of training necessary for leadership in the profession. To engage in this profession with competence, four years of undergraduate study and at least one year of postgraduate study are recommended. For those who plan to work in highly technical development or fundamental research, additional graduate study is desirable.

The degree of Master of Science is offered under the general regulations of the University. The master's program, requiring a minimum of 45 units of graduate study, should be considered by those with the ability and desire to make a life work of professional practice or continued graduate study.

The degree of Doctor of Philosophy is offered under the general regulations of the University. The doctoral program, requiring a minimum of 135 units of graduate study, should be considered by those with the ability and desire to make a life work of research or teaching.

Application for Admission

Applications for graduate admission in Electrical Engineering (EE) should be completed electronically at the Graduate Admissions (http://gradadmissions.stanford.edu) web site. See the Electrical Engineering graduate admissions (http://ee.stanford.edu/admissions) web site for department specific informaiton. The application deadline for full-time admission for Autumn Quarter 2016-17 is December 8, 2015.

Electrical Engineering Course Catalog Numbering System

Electrical Engineering courses are typically numbered according to the year in which the courses are normally taken.

Number	Year
010-099	first or second year undergraduate
100-199	second through fourth year undergraduate
200-299	mezzanine courses for advanced undergraduate or first-year graduate
300-399	second through fourth year graduate
400-499	specialized courses for advanced graduate
600-799	special summer courses

The Department of Electrical Engineering (EE) offers courses in the following areas:

- Biomedical Devices and Bioimaging
- Communication Systems: wireless, optical, wireline
- Control, Learning, and Optimization
- Electronic and Magnetic Devices
- Energy: solar cells, smart grid, load control
- Environmental and Remote Sensing: sensor nets, radar systems, space
- Fields and Waves
- Graphics, HCI, Computer Vision, Photography
- Information Theory and Coding: Image and data compression, denoising
- Integrated Circuit Design: MEMs, sensors, analog, RF
- Network Systems and Science: Next gen internet, wireless networks
- Nano and Quantum Science
- Nanofabrication Science and Technology
- Photonic Devices
- Systems Software: OS, compilers, languages
- Systems Hardware: architecture, VLSI, embedded systems

Areas of Research in Electrical Engineering

Candidates for advanced degrees participate in the research activities of the department as paid research assistants or as students of individual faculty members. At any one time, certain areas of research have more openings than others. At present, faculty members and students are actively engaged in research in the following areas:

Hardware/Software Systems

- Data Science
- Secure Distributed Systems
- Energy-Efficient Hardware Systems
- Integrated Circuits and Power Electronics
- Software Defined Networking
- Mobile Networking

Information Systems and Science

- Bio-Medical Imaging
- Communications Systems
- Control & Optimization
- Data Science
- Information Theory and Applications
- Societal Networks
- Signal Processing and Multimedia

Physical Science and Technology

- Biomedical Devices, Sensors and Systems
- Electronic Devices
- Energy Harvesting and Conversion
- Integrated Circuits and Power Electronics
- Nanotechnology, Nanofabrication and NEMS/MEMS
- Photonics, Nanoscience and Quantum Technologies

For additional information, see the Department of Electrical Engineering's Research (https://ee.stanford.edu/research/the-big-picture) web site.

Undergraduate Programs in Electrical Engineering

To major in Electrical Engineering (EE), undergraduates should follow the depth sequence in the "Undergraduate Degree in Electrical Engineering" section of this bulletin. Students must have a program planning sheet approved by their adviser and the department before the end of the quarter following the quarter in which they declare the EE major. A final version of the completed and signed program sheet is due to the department no later than one month prior to the quarter of senior year. Program sheets are available at http://ughb.stanford.edu. Majors must receive at least a 2.0 grade point average (GPA) in courses taken for the EE depth requirement; all classes must be taken for a letter grade.

Students interested in a minor should consult the "Minor in Electrical Engineering" section of this bulletin.

A Stanford undergraduate may work simultaneously toward the B.S. and M.S. degrees. University requirements for the coterminal M.A. or M.S. are described in the "Coterminal Bachelor's and Master's Degrees" section of this bulletin. For University coterminal degree program rules and University application forms, see http://studentaffairs.stanford.edu/registrar/publications#Coterm.

Electrical Engineering (EE)

Completion of the undergraduate program in Electrical Engineering leads to the conferral of the Bachelor of Science in Electrical Engineering.

Mission of the Undergraduate Program in Electrical Engineering

The mission of the undergraduate program of the Department of Electrical Engineering is to augment the liberal education expected of all Stanford undergraduates, to impart basic understanding of electrical engineering and to develop skills in the design and building of systems that directly impact societal needs. The program includes a balanced foundation in the physical sciences, mathematics and computing; core courses in electronics, information systems and digital systems; and develops specific skills in the analysis and design of systems. Students in the major have broad flexibility to select from many specialization areas beyond the core, including areas in electronics, optics, information systems and hardware and software systems as well as application-oriented cross-cuts in bio-instrumentation and bio-imaging, energy and environment and music. The program prepares students for a broad range of careers—both industrial and government—as well as for professional and academic graduate education.

Requirements

Mathematics

MATH 41	Calculus	5
MATH 42	Calculus	5
Select one 2-course sequence:		10
CME 100 & CME 102	Vector Calculus for Engineers and Ordinary Differential Equations for Engineers (Same as ENGR 154)	
MATH 52 & MATH 53	Integral Calculus of Several Variables and Ordinary Differential Equations with Linear Algebra	
EE Math. One additional 100-level course. Select one of the following:		3
EE 102B	Signal Processing and Linear Systems II (if not used in Depth)	
EE 103	Introduction to Matrix Methods	
EE 142	Engineering Electromagnetics	
CME 104/ ENGR 155B	Linear Algebra and Partial Differential Equations for Engineers	
MATH 113	Linear Algebra and Matrix Theory	
CS 103	Mathematical Foundations of Computing	

Statistics/Probability. Select one of the following: [1]		3-4
EE 178	Probabilistic Systems Analysis (Preferred)	
CS 109	Introduction to Probability for Computer Scientists	
Science		
Select one of the following sequences:		8
PHYSICS 41 & PHYSICS 43	Mechanics and Electricity and Magnetism [2]	
PHYSICS 61 & PHYSICS 63	Mechanics and Special Relativity and Electricity, Magnetism, and Waves	
Science elective. One additional 4-5 unit course from approved list in Undergraduate Handbook, Figure 3-2. [3]		4-5
Technology in Society		
One course, see Basic Requirement 4 in the School of Engineering section		3-5
Engineering Fundamentals [4]		
Select one of the following:		
CS 106B/ ENGR 70B	Programming Abstractions	5
or CS 106X/ ENGR 70X	Programming Abstractions (Accelerated)	
At least two additional courses, at least one of which is not in EE or CS (CS 106A is not allowed). Choose from table in Undergraduate Handbook, Figure 3-4. One from ENGR 40 or ENGR 40M recommended.		8-10
Writing in the Major (WIM)		
Select one of the following:		3-4
EE 109	Digital Systems Design Lab (WIM/Design)	
EE 133	Analog Communications Design Laboratory (WIM/ Design)	
EE 134	Introduction to Photonics (WIM/Design)	
EE 153	Power Electronics (WIM/Design)	
EE 155	Green Electronics (WIM/Design)	
EE 168	Introduction to Digital Image Processing (WIM/ Design)	
EE 191W	Special Studies and Reports in Electrical Engineering (WIM; Department approval required) [5]	
CS 194W	Software Project (WIM/Design)	
Core Electrical Engineering Courses		
EE 100	The Electrical Engineering Profession [6]	1
EE 101A	Circuits I	4
EE 102A	Signal Processing and Linear Systems I	4
EE 108	Digital System Design	4
Physics in Electrical Engineering. Students must complete one of the following courses:		3-5
EE 65	Modern Physics for Engineers (Preferred)	
EE 142	Engineering Electromagnetics [7]	
Depth Courses		14
Select four courses from one of the following Depth areas. Courses must include one required course, one Design course, and 2 additional courses.		
Design Course		3-4
Select one of the following:		
EE 109	Digital Systems Design Lab (WIM/Design)	
EE 133	Analog Communications Design Laboratory (WIM/ Design)	
EE 134	Introduction to Photonics (WIM/Design)	
EE 153	Power Electronics (WIM/Design)	
EE 155	Green Electronics (WIM/Design)	
EE 168	Introduction to Digital Image Processing (WIM/ Design)	
EE 262	Two-Dimensional Imaging (Design)	
EE 264	Digital Signal Processing [8]	
CS 194W	Software Project (WIM/Design)	
Additional Electives		12
May include up to two additional Engineering Fundamentals, any CS 193 course and any letter graded EE or EE Related courses (minus any previously noted restrictions). Freshman and Sophmore seminars, EE191 and CS 106A do not count toward the 60 units.		

1. CME 106 or STATS 116 can also fulfill the Statistics/Probability requirement, but these are not preferred.
2. The EE introductory class ENGR 40 or ENGR 40M may be taken concurrently with PHYSICS 43. PHYSICS 43 is not a prerequisite for ENGR 40 or 40M. Many students find the material complementary in terms of fundamental and applied perspectives on electronics.
3. A minimum of 12 science units must be taken. A minimum of 40 math and science units combined must be taken.
4. EE Engineering Topics: Fundamentals and Depth courses must total 60 units minimum.
5. EE 191W may satisfy WIM only if it is a follow-up to an REU, independent study project or as part of an honors thesis project where a faculty agrees to provide supervision of writing a technical paper and with suitable support from the Writing Center.
6. For upper division students, a 200-level seminar in their depth area will be accepted, on petition.
7. EE 142 cannot be double counted. It may be used for only one of: Math; Physics in Electrical Engineering; or as a depth elective.
8. To satisfy Design, EE 264 must be taken for 4 units and complete the laboratory project.

Depth Areas

		Units
Bio-electronics and Bio-imaging		
EE 101B	Circuits II (Required)	4
or EE 102B	Signal Processing and Linear Systems II	
EE 122B	Introduction to Biomedical Electronics	3
EE 124	Introduction to Neuroelectrical Engineering	3
EE 134	Introduction to Photonics (WIM/Design)	4
EE 168	Introduction to Digital Image Processing (WIM/ Design)	4
EE 169	Introduction to Bioimaging	3
EE 202	Electrical Engineering in Biology and Medicine	3
EE 225	Biochips and Medical Imaging	3
MED 275B	Biodesign: Medical Technology Innovation	2-5
Circuits and Devices		
EE 101B	Circuits II (Required)	4
EE 114	Fundamentals of Analog Integrated Circuit Design	3
EE 116	Semiconductor Device Physics	3
EE 118	Introduction to Mechatronics	4
EE 122A	Analog Circuits Laboratory	3
EE 133	Analog Communications Design Laboratory (WIM/ Design)	4
EE 153	Power Electronics (WIM/Design)	3-4
EE 155	Green Electronics (WIM/Design)	4
EE 212	Integrated Circuit Fabrication Processes	3
EE 213	Digital MOS Integrated Circuits	3
EE 214B	Advanced Analog Integrated Circuit Design	3
EE 216	Principles and Models of Semiconductor Devices	3

EE 271	Introduction to VLSI Systems	3
Computer Hardware		
CS 107	Computer Organization and Systems (Prerequisite for EE 180)	3-5
or CS 107E	Computer Systems from the Ground Up	
EE 107	Embedded Networked Systems	3
EE 180	Digital Systems Architecture (Required)	4
EE 109	Digital Systems Design Lab (WIM/Design)	4
EE 118	Introduction to Mechatronics	4
EE 155	Green Electronics (WIM/Design)	4
EE 213	Digital MOS Integrated Circuits	3
EE 271	Introduction to VLSI Systems	3
EE 273	Digital Systems Engineering	3
EE 282	Computer Systems Architecture	3
CS 110	Principles of Computer Systems	3-5
CS 140	Operating Systems and Systems Programming	3-4
CS 143	Compilers	3-4
CS 144	Introduction to Computer Networking	3-4
CS 148	Introduction to Computer Graphics and Imaging	3-4
Computer Software		
CS 107	Computer Organization and Systems (Prerequisite for EE 180)	3-5
or CS 107E	Computer Systems from the Ground Up	
EE 107	Embedded Networked Systems	3
EE 180	Digital Systems Architecture (Required)	4
CS 108	Object-Oriented Systems Design	3-4
CS 110	Principles of Computer Systems	3-5
CS 140	Operating Systems and Systems Programming	3-4
CS 143	Compilers	3-4
CS 144	Introduction to Computer Networking	3-4
CS 145	Introduction to Databases	3-4
CS 148	Introduction to Computer Graphics and Imaging	3-4
CS 155	Computer and Network Security	3
EE 155	Green Electronics (WIM/Design)	4
CS 194W	Software Project (WIM/Design)	3
Energy and Environment		
EE 101B	Circuits II (Required)	4
or EE 180	Digital Systems Architecture	
EE 116	Semiconductor Device Physics	3
EE 134	Introduction to Photonics (WIM/Design)	4
EE 151	Sustainable Energy Systems	3
EE 155	Green Electronics (WIM/Design)	4
EE 153	Power Electronics (WIM/Design)	3-4
EE 168	Introduction to Digital Image Processing (WIM/Design)	3-4
EE 263	Introduction to Linear Dynamical Systems	3
EE 293A	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	3-4
EE 293B	Fundamentals of Energy Processes	3
CEE 155	Introduction to Sensing Networks for CEE	4
CEE 107A	Understanding Energy (Formerly CEE 173A)	3
CEE 176A	Energy Efficient Buildings	3-4
CEE 176B	Electric Power: Renewables and Efficiency	3-4
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3
MATSCI 156	Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution	3-4
ME 185	Electric Vehicle Design	3
Music		
EE 102B	Signal Processing and Linear Systems II (Required)	4
or MUSIC 320B	Introduction to Audio Signal Processing Part II: Digital Filters	
EE 109	Digital Systems Design Lab (WIM/Design)	4
EE 122A	Analog Circuits Laboratory	3
EE 264	Digital Signal Processing	4
MUSIC 256A	Music, Computing, Design I: Art of Design for Computer Music	1-4
MUSIC 256B	Music, Computing, Design II: Virtual and Augmented Reality for Music	3-4
MUSIC 320A	Introduction to Audio Signal Processing Part I: Spectrum Analysis	3-4
MUSIC 420A	Signal Processing Models in Musical Acoustics	3-4
MUSIC 421A	Audio Applications of the Fast Fourier Transform	3-4
MUSIC 422	Perceptual Audio Coding	3
MUSIC 424	Signal Processing Techniques for Digital Audio Effects	3-4
Photonics, Solid State and Electromagnetics		
EE 101B	Circuits II (Required)	4
EE 116	Semiconductor Device Physics	3
EE 134	Introduction to Photonics (WIM/Design)	4
EE 136	Introduction to Nanophotonics and Nanostructures	3
EE 142	Engineering Electromagnetics	3
EE 216	Principles and Models of Semiconductor Devices	3
EE 222	Applied Quantum Mechanics I	3
EE 223	Applied Quantum Mechanics II	3
EE 228	Basic Physics for Solid State Electronics	3
EE 236A	Modern Optics	3
EE 236B	Guided Waves	3
EE 242	Electromagnetic Waves	3
EE 247	Introduction to Optical Fiber Communications	3
Signal Processing, Communications and Controls		
EE 102B	Signal Processing and Linear Systems II (Required)	4
EE 107	Embedded Networked Systems	3
EE 124	Introduction to Neuroelectrical Engineering	3
EE 169	Introduction to Bioimaging	3
EE 261	The Fourier Transform and Its Applications	3
EE 263	Introduction to Linear Dynamical Systems	3
EE 264	Digital Signal Processing	4
EE 278	Introduction to Statistical Signal Processing	3
EE 279	Introduction to Digital Communication	3
ENGR 105	Feedback Control Design	3
ENGR 205	Introduction to Control Design Techniques	3

For additional information and sample programs see the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

Honors Program

The Department of Electrical Engineering offers a program leading to a Bachelor of Science in Electrical Engineering with Honors. This program offers a unique opportunity for qualified undergraduate majors to conduct independent study and research at an advanced level with a faculty mentor, graduate students, and fellow undergraduates.

Admission to the honors program is by application. Declared EE majors with a grade point average (GPA) of at least 3.5 in Electrical Engineering are eligible to submit an application. Applications must be submitted by Autumn quarter of the senior year, be signed by the thesis adviser and second reader (one must be a member of the EE Faculty), and include an honors proposal. Students need to declare honors on Axess.

In order to receive departmental honors, students admitted to the honors program must:

1. Submit an application, including the thesis proposal, by autumn quarter of senior year signed by the thesis advisor and second reader (one must be a member of the Electrical Engineering faculty).
2. Declare the EE Honors major in Axess before the end of autumn quarter of senior year.
3. Maintain a grade point average of at least 3.5 in Electrical Engineering courses.
4. Complete at least 10 units of EE 191 or EE 191W with thesis advisor for a letter grade. EE 191 units do not count toward the required 60 units, with the exception of EE 191W if approved to satisfy WIM.
5. Submit one final copy of the honors thesis approved by the advisor and second reader to the EE Degree Progress Officer by May 15.
6. Attend poster and oral presentation held at the end of spring quarter or present in another suitable forum approved by the faculty adviser.

Electrical Engineering (EE) Minor

The options for completing a minor in EE are outlined below. Students must complete a minimum of 23-25 units, as follows:

		Units
Select one of the following courses:		5
EE 65	Modern Physics for Engineers	
ENGR 40	Introductory Electronics	
ENGR 40M	An Intro to Making: What is EE	
Select one of the following options:		8
Option I:		
EE 101A	Circuits I	
EE 101B	Circuits II	
Option II:		
EE 102A	Signal Processing and Linear Systems I	
EE 102B	Signal Processing and Linear Systems II	
Option III:		
EE 108	Digital System Design	
EE 180	Digital Systems Architecture	
In addition, four letter-graded EE or Related courses at the 100-level or higher must be taken (12 units minimum). CS 107 is required as a prerequisite for EE 180, but can count as one of the four classes.		12

Master of Science in Electrical Engineering

Students with undergraduate degrees in physics, mathematics, or related sciences, as well as in various branches of engineering, are invited to apply for admission. They should typically be able to complete the master's degree in five quarters; note that many courses are not taught during the summer. Capable students without formal undergraduate preparation in electrical engineering may also be admitted for graduate study. Such students may have graduated in any field and may hold either the B.S. or B.A. degree. Graduate study in electrical engineering demands that students be adequately prepared in areas such as circuits, digital systems, fields, lab work, mathematics, and physics.

It is the student's responsibility, in consultation with an adviser, to determine whether the prerequisites for advanced courses have been met. Prerequisite courses ordinarily taken by undergraduates may be included as part of the graduate program of study. However, if the number of these is large, the proposed program may contain more than the minimum 45 units, and the time required to meet the degree requirements may be increased.

The master's degree program may provide advanced preparation for professional practice or for teaching at the junior college level. The faculty does not prescribe specific courses to be taken. Each student, with the help of a program adviser, prepares an individual program and submits it to the department for approval. The Program Proposal must be submitted to the Degree Progress Office before the end of the first quarter of graduate study (second quarter for Honors Cooperative Program students); a final revised version is due early in the final quarter of study, prior to degree conferral. Detailed requirements and instructions are available at http://ee.stanford.edu/gradhandbook. All requirements for a master's degree must be completed within three years after the student's first term of enrollment in the master's program (five years for Honors Cooperative Program students).

University Coterminal Requirements

Coterminal master's degree candidates are expected to complete all master's degree requirements as described in this bulletin. University requirements for the coterminal master's degree are described in the "Coterminal Master's Program (http://exploredegrees.stanford.edu/cotermdegrees)" section. University requirements for the master's degree are described in the "Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees/#masterstext)" section of this bulletin.

After accepting admission to this coterminal master's degree program, students may request transfer of courses from the undergraduate to the graduate career to satisfy requirements for the master's degree. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis.

In this master's program, courses taken during or after the first quarter of the sophomore year are eligible for consideration for transfer to the graduate career; the timing of the first graduate quarter is not a factor. No courses taken prior to the first quarter of the sophomore year may be used to meet master's degree requirements.

Course transfers are not possible after the bachelor's degree has been conferred.

The University requires that the graduate adviser be assigned in the student's first graduate quarter even though the undergraduate career may still be open. The University also requires that the Master's Degree Program Proposal be completed by the student and approved by the department by the end of the student's first graduate quarter.

Master of Science with Distinction in Research

A student who wishes to pursue the M.S. in EE with distinction in research must first identify a faculty adviser who agrees to supervise and support the research work. The research adviser must be a member of the Academic Council and must hold an appointment in Electrical Engineering. The student and principal adviser must also identify another faculty member, who need not be in the Department of Electrical Engineering, to serve as a secondary adviser and reader for the research report. In addition, the student must complete the following requirements beyond those for the regular M.S. in EE degree:

1. *Research Experience*—The program must include significant research experience at the level of a half-time commitment over the course of three academic quarters. In any given quarter, the half-time research commitment may be satisfied by:

   a. a 50 percent appointment to a departmentally supported research assistantship,
   b. 6 units of independent study (EE 300, EE 390, or EE 391)
   c. a prorated combination of the two (such as a 25 percent research assistantship supplemented by 3 units of independent study).
   d. An equivalent research experience while fully supported on a Stanford-funded or externally funded fellowship. Student and research adviser must document the planned research-experience before the quarter starts and its completion at the end. Note: Fellowship must provide full support at the 10-unit tuition level, and allow the student to pursue degree-related research in addition to his/her fulltime course enrollment. This research must be carried out under the direction of the primary or secondary adviser.
2. *Supervised Writing and Research*—In addition to the research experience outlined in the previous requirement, students must enroll in at least 3 units of independent research (EE 300, EE 390, or EE 391 under the direction of their primary or secondary adviser. These units should be closely related to the research described in the first requirement, but focused more directly on the preparation of the research report described in the next section. The writing and research units described in parts (1) and (2) may be counted toward the 45 units required for the degree.
3. All independent study units (EE 300, EE 390, or EE 391) must be taken for letter grades and a GPA of 3.0 (B) or better must be maintained.
4. *Research Report*—Students must complete a significant report describing their research and its conclusions. The research report represents work that is publishable in a journal or at a high-quality conference, although it is presumably longer and more expansive in scope than a typical conference paper. A copy of the research report must be submitted to the student services office in the department three weeks before the beginning of the examination period in the student's final quarter. Both the primary and secondary adviser must approve the research report before the distinction-in-research designation can be conferred.

The Honors Cooperative Program

Many of the department's graduate students are supported by the Honors Cooperative Program (HCP), which makes it possible for academically qualified engineers and scientists in nearby companies to be part-time master's students in Electrical Engineering while continuing nearly full-time professional employment. Prospective HCP students follow the same admission process and must meet the same admission requirements as full-time master's students. For more information regarding the Honors Cooperative Program, see the "School of Engineering" section of this bulletin.

Joint Electrical Engineering and Law Degree (J.D./M.S.)

The Department of Electrical Engineering and the School of Law offer a joint degree program leading to an M.S. degree in EE combined with a J.D. degree. The J.D./M.S. program is designed for students who wish to prepare themselves for careers that involve both Law and Electrical Engineering.

Students interested in this joint degree program must apply to and gain admission separately from the Department of Electrical Engineering and the School of Law, and as an additional step, secure consent from both academic units to pursue both degrees simultaneously. Interest in the program should be noted on a student's application to each academic unit. A student currently enrolled in either the Department of Electrical Engineering or the School of Law may apply for admission to the other academic unit and for joint degree status after commencing study in that unit.

Joint degree students may elect to begin their study in either the Department of Electrical Engineering or the School of Law. Faculty advisers from each academic unit participate in the planning and supervising of the student's joint program. In the first year of the joint degree program, students must be enrolled full-time in the School of Law. Students must satisfy the requirements for both the J.D. and the M.S. degrees as specified in the *Stanford Bulletin*.

The Electrical Engineering Department approves courses from the Law School that may count toward the M.S. degree in Electrical Engineering, and the Law School approves courses from the Department of Electrical Engineering that may count toward the J.D. degree. In either case, approval may consist of a list applicable to all joint degree students or may be tailored to each individual student's program.

No more than 45 quarter hours of approved courses may be counted toward both degrees. No more than 36 quarter hours of courses that originate outside the School of Law may count toward the Law degree. To the extent that courses under this joint degree program originate outside of the School of Law but count toward the Law degree, the School of Law credits permitted under Section 17(1) of the Law School Regulations shall be reduced on a unit-per-unit basis but not below zero.

The maximum number of School of Law units that may be counted toward the M.S. degree in Electrical Engineering is the greater of:

1. 12 units, or
2. the maximum number of units from courses outside of the department that M.S. candidates in Electrical Engineering are permitted to count toward the M.S. degree under general departmental guidelines, or as set forth in the case of a particular student's individual program.

Tuition and financial aid arrangements are typically administered through the school in which the student is enrolled.

Joint Electrical Engineering and Master's in Business Administration Degree (M.S./M.B.A.)

The Department of Electrical Engineering and the Graduate School of Business offer a joint degree program leading to an M.S. degree in EE combined with an M.B.A. degree. The joint program offers students an opportunity to develop advanced technical and managerial skills in preparation for careers in existing and new technology ventures.

Admission to the joint M.S./M.B.A. program requires that students apply and be accepted independently to both the Electrical Engineering Department at the School of Engineering and the Graduate School of Business. Students may apply concurrently, or elect to begin their course of study in EE and apply to the GSB during their first year.

Doctor of Philosophy in Electrical Engineering

The University requirements for the Ph.D. degree are described in the "Graduate Degrees" section of this bulletin.

Admission to a graduate program does not imply that the student is a candidate for the Ph.D. degree. Advancement to candidacy requires superior academic achievement, satisfactory performance on a qualifying examination, and sponsorship by two faculty members. Enrollment in EE 391, Special Studies, is recommended as a means for getting acquainted with a faculty member who might be willing to serve as the dissertation advisor.

Students admitted to the Ph.D. program must sign up to take the department qualifying examination, given once a year in winter quarter.

Students are allowed two attempts to pass the examination. Students are encouraged to take the exam in their first year of study. The first attempt must be made no later than the second year of study. Students who have never taken the qualifying examination by the end of the second year of study will be dismissed from the Ph.D. program for failure to progress. Such students may be allowed to complete a master's degree in Electrical Engineering instead. Students who do not pass the qualifying examination after two attempts will be dismissed from the Ph.D. program for failure to progress. Such students may be allowed to complete a master's degree in Electrical Engineering instead.

Upon completion of the qualifying examination and after securing agreement by two faculty members to serve as dissertation adviser and second reader, the student files an Application for Candidacy for Doctoral Degree. The dissertation adviser must be a member of the Academic Council. One of the two faculty members must have either a full, joint or courtesy appointment in the Electrical Engineering department. Students are required to advance to candidacy prior to the end of their second year in the graduate program. Students who do not advance to candidacy by the end of their second year will be dismissed from the Ph.D. program for failure to progress.

The Ph.D. in Electrical Engineering is a specialized degree, and is built on a broad base of physics, mathematics, and engineering skills. The course program is expected to reflect competency in Electrical Engineering and specialized study in other areas relevant to the student's research focus. 90 units must be completed at Stanford beyond the 45 units for a master's degree (completed either at Stanford or at another institution and transferred in via the Application for Graduate Residency Credit form), for a total of 135 units. Students must complete 21 units of letter-graded lecture courses in related advanced physics, mathematics, engineering, or computer science courses, depending on the area of research. 12 of these 21 units must be EE/EE Related courses at the 200 level or higher. The remaining 69 units should be research with the dissertation advisor (EE 400, or the corresponding course number if the dissertation advisor's primary appointment is in another department).

Only after receiving department approval of the Application for Candidacy does the student become a candidate for the Ph.D. degree.

For additional information, see the department's web site (http://ee.stanford.edu/gradhandbook).

Financial Assistance

The department awards a limited number of fellowships, teaching and course assistantships, and research assistantships to incoming graduate students. Applying for financial assistance is part of the admission application.

Ph.D. Minor in Electrical Engineering

For a minor in Electrical Engineering, students must fulfill the M.S. degree depth requirement, complete at least 20 units of lecture course work at the 200-level or higher in Electrical Engineering (of which 15 units must be letter-graded), and have the Application for Ph.D. Minor approved by the EE department and the major department. A grade point average of at least 3.35 on these courses is required.

Emeriti: (Professors) Clayton W. Bates, Richard Bube, John Cioffi*, Donald C. Cox, Von R. Eshleman, Michael J. Flynn*, Joseph W. Goodman, Robert M. Gray, Stephen E. Harris, Martin E. Hellman, Umran S. Inan*, Thomas Kailath*, Gordon S. Kino, Marc Levoy, Albert Macovski*, Edward J. McCluskey, Malcolm M. McWhorter, James D. Meindl, Teresa Meng, Richard H. Pantell, R. Fabian W. Pease, Leonard Tyler*, Robert L. White, Bernard Widrow, Bruce A. Wooley, Yoshihisa Yamamoto*; (*Associate Professor*) Bruce B. Lusignan; *(Professors, Research)* Donald L. Carpenter*, Antony Fraser-Smith*, C. Robert Helms, Leonid Kazovsky, Ingolf Lindau*, David Luckham, Arogyaswami J. Paulraj, Calvin F. Quate (**Recalled to active duty*)

Chair: Abbas El Gamal

Associate Chairs: Robert W. Dutton *(Undergraduate Education),* Olav Solgaard *(Graduate Education),* Howard Zebker *(Admissions)*

Academic Affairs Committee Chair: Joseph M. Kahn

Professors: Nicholas Bambos, Dan Boneh, Stephen P. Boyd, Robert W. Dutton, Abbas El Gamal, Shanhui Fan, Hector Garcia-Molina, Bernd Girod, Andrea G. Goldsmith, Patrick Hanrahan, James S. Harris, John L. Hennessy, Lambertus Hesselink, Mark A. Horowitz, Roger T. Howe, Joseph M. Kahn, Gregory T. A. Kovacs, Sanjay Lall, Thomas H. Lee, Nick McKeown, David A. B. Miller, Andrea Montanari, Dwight G. Nishimura, Oyekunle Olukotun, Brad G. Osgood, John M. Pauly, James D. Plummer, Balaji Prabhakar, Mendel Rosenblum, Krishna Saraswat, Krishna V. Shenoy, Hyongsok Tom Soh, Olav Solgaard, Fouad A. Tobagi, David Tse, Benjamin Van Roy, Jelena Vuckovic, Shan X. Wang, Tsachy Weissman, Jennifer Widom, H. S. Philip Wong, S. Simon Wong, Howard Zebker

Associate Professors: Dawson Engler, John T. Gill III, Christoforos E. Kozyrakis, Philip Levis, Subhasish Mitra, Boris Murmann, Eric Pop

Assistant Professors: Amin Arbabian, John Duchi, Audrey Ellerbee, Jonathan Fan, Sachin Katti, Ayfer Ozgur Aydin, Ada Poon, Juan Rivas, Gordon Wetzstein

Professors (Research): William J. Dally, James F. Gibbons, Butrus Khuri-Yakub, Yoshio Nishi, Piero Pianetta

Courtesy Professors: Stacey Bent, Kim Butts-Pauly, Emmanuel Candes, EJ Chichilnisky, Amir Dembo, David L. Dill, Per Enge, Ron Fedkiw, Gary Glover, Peter Glynn, Leonidas Guibas, Monica S. Lam, Craig Levin, David G. Luenberger, Michael McConnell, John C. Mitchell, Sandy Napel, Richard Olshen, John Ousterhout, Norbert Pelc, Julius Smith, Brian Wandell, Lei Xing, Yinyu Ye

Courtesy Associate Professors: Kwabena Boahen, Utkan Demirci, Brian Hargreaves, Ramesh Johari, Andrew Ng, Amin Saberi, Daniel Spielman,

Courtesy Assistant Professors: Mohsen Bayati, Sigrid Close, Adam de la Zerda, Surya Ganguli, Jin Hyung Lee, David Liang, Marco Pavone, Ram Rajagopal, Debbie Senesky

Lecturers: Dennis Allison, Andrea Di Blas, Abbas Emami-Naeini, Leslie Field, Nicola Femia, Andrew Freeman, Laurent Blaise Giovangrandi, My Le, Heiner Litz, Blanka Magyari Kope, Roger Melen, Scott Murray, David Obershaw, Dan O'Neill, John Provine, Partha Ranganathan, Sriram Sundararajan, Jason Stinson, James Weaver

Consulting Professors: Rick Bahr, Richard Dasher, Michael Garner, Fred M. Gibbons, Dimitry Gorinevsky, Bob S. Hu, Theodore Kamins, David Leeson, Fernando Mujica, Guru Parulkar, Stephen Ryu, Ronald Schafer, Ashok Srivastava, John Wenstrand

Consulting Associate Professors: Jun Ye

Consulting Assistant Professor: Aneesh Nainani

Visiting Professors: Lihua Li, Yingxu Wang

Visiting Associate Professors: Diego Gutierrez, Shiyan Hu, SoYoung Kim, Liyang Yu, Feng Zhan

Visiting Assistant Professors: Meik Dorpinghaus, Daisuke Kanemoto, Xiumin Shi