The educational objectives of the program are:

- used in evaluating students and the department's undergraduate program.
- The department expects undergraduate majors in the program to be able to
  - Learning Outcomes
  - (Undergraduate)

  - Careers in government agencies, the corporate sector, or for future study in state, photonics, and electromagnetics. The program prepares students for software; music; signal processing, communication and controls; and solid state, photonics, and electromagnetics. The program prepares students for careers in government agencies, the corporate sector, or for future study in graduate or professional schools.

- 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 biomedical sensing and imaging; 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.

- Applications for Admission

  - Applications for graduate admission in Electrical Engineering (EE) should be completed electronically at http://gradadmissions.stanford.edu. For information concerning Electrical Engineering graduate admissions, see http://ee-admissions.stanford.edu. The application deadline for admission for Autumn Quarter 2013-14 is December 18, 2012.

- Electrical Engineering Course Catalog Numbering System

  - Electrical Engineering courses are typically numbered according to the year in which the courses are normally taken.
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. A new applicant should express a second choice of research interest in the event that there are no vacancies in the primary area of interest. At present, faculty members and students are actively engaged in research in the following areas:

- Integrated Electronic Systems Technology
  - MEMS, Sensors, Actuators
  - Devices
- Bio-EE
  - Instrumentation
  - Imaging
  - Analysis
- Photonics/EM/Quantum
  - Photonics
  - Nano
  - Quantum
  - Communication
  - Imaging
  - Radio
- Information Systems
  - Information Theory and Coding
  - Communications
  - Control & Optimization
  - Signal Processing
  - Stochastic Systems

For additional information, see the Department of Electrical Engineering’s Research page at http://ee.stanford.edu/research.php.

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 coterminous M.A. or M.S. are described in the “Coterminal Bachelor’s and Master’s Degrees” section of this bulletin. For University coterminous 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 a basic understanding of electrical engineering built on a foundation of physical science, mathematics, computing, and technology, and to provide majors in the department with knowledge of electrical engineering principles along with the required supporting knowledge of mathematics, science, computing, and engineering fundamentals. The program develops students’ skills in performing and designing experimental projects and communicating their findings to the scientific community effectively. Students in the major are required to select one sub-discipline for specialization. Choices include bioelectronics and bioimaging; circuits and devices; computer hardware; computer software; music; signal processing, communication and controls; and solid state, photonics, and electromagnetics. The program prepares students for careers in government agencies, the corporate sector, or for future study in graduate or professional schools.

Requirements

<table>
<thead>
<tr>
<th>Mathematics (28-30)</th>
<th>Units</th>
</tr>
</thead>
</table>
Select one of the following sequences:

MATH 51 & MATH 52
Linear Algebra and Differential Calculus of Several Variables
and Integral Calculus of Several Variables

CME 100 & CME 104
Vector Calculus for Engineers
and Linear Algebra and Partial Differential Equations for Engineers (Same as ENGR 154 & ENGR 155B)

Select one of the following:

MATH 53
Ordinary Differential Equations with Linear Algebra

CME 102/ENGR 155A
Ordinary Differential Equations for Engineers

Select one of the following:

EE 178
Probabilistic Systems Analysis (Preferred)

STATS 116
Theory of Probability

MATH 151
Introduction to Probability Theory

CME 106/ENGR 155C
Introduction to Probability and Statistics for Engineers

Science (15-17)

Select one of the following sequences:

PHYSICS 41
Mechanics

PHYSICS 43
and Electricity and Magnetism

PHYSICS 61
Mechanics and Special Relativity

PHYSICS 63
and Electricity, Magnetism, and Waves

Math or Science electives

Select one of the following sequences:

Engineering Fundamentals (11-15)

Three courses minimum, see Basic Requirement 3 in the School of Engineering section

CS 106B/ENGR 70B
Programming Abstractions

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. One from ENGR 40, ENGR 40N or ENGR 40P recommended.

Core Courses Engineering Depth (46-62)

Minimum 68 Engineering Topics units; see Basic Requirement 5 in the School of Engineering section

EE 100
The Electrical Engineering Profession

EE 101A
Circuits I

EE 101B
Circuits II

EE 102A
Signal Processing and Linear Systems I

EE 102B
Signal Processing and Linear Systems II

EE 108A
Digital Systems I

EE 108B
Digital Systems II

Physics in Electrical Engineering:

EE 41/ENGR 40P
Physics of Electrical Engineering

or EE 141
Engineering Electromagnetics

Specialty courses

One course in Design

Electrical Engineering electives

Total Units

1. A minimum of 12 science units must be taken. A minimum of 45 math and science units combined must be taken.
2. EE 191W may satisfy WIM if used for Honors Thesis, REU (following a summer REU project), or a research project. A written report that has gone through revision with an advisor is required. An advisor from the Writing Center is recommended.
3. EE 41/ENGR 40P can meet this requirement only if it is not used to fulfill the Engineering Fundamentals requirement.
4. Three courses from one of the specialty areas shown below (consultation with an adviser in the selection of these courses is especially important):
5. The design course may be part of the specialty sequence. The following courses satisfy this requirement: EE 109, EE 133, EE 134, EE 168, EE 262, EE 265, CS 194W.
6. May include up to two additional Engineering Fundamentals. May include up to 10 units of EE 191 and EE 191W. May include any CS 193 course.

Specialty Areas

Bioelectronics and Bioimaging (23)

EE 122B
Introduction to Biomedical Electronics

EE 124
Introduction to Neuroelectrical Engineering

EE 134
Introduction to Photonics (WIM)

EE 168
Introduction to Digital Image Processing (WIM)

EE 169
Introduction to Bioimaging

EE 202
Electrical Engineering in Biology and Medicine

EE 225
Bio-chips, Imaging and Nanomedicine

Circuits and Devices (26)

EE 114
Fundamentals of Analog Integrated Circuit Design

EE 116
Semiconductor Device Physics

EE 122A
Analog Circuits Laboratory

EE 133
Analog Communications Design Laboratory (WIM)

EE 212
Integrated Circuit Fabrication Processes

EE 214B
Advanced Analog Integrated Circuit Design

EE 216
Principles and Models of Semiconductor Devices

EE 271
Introduction to VLSI Systems

Computer Hardware (16-18)

EE 109
Digital Systems Design Lab (WIM)

EE 271
Introduction to VLSI Systems

EE 273
Digital Systems Engineering

EE 282
Computer Systems Architecture

CS 107
Computer Organization and Systems

Computer Software (27-37)

CS 107
Computer Organization and Systems
### Electrical Engineering

#### CS 108
Object-Oriented Systems Design 3-4

#### CS 140
Operating Systems and Systems Programming 3-4

#### CS 143
Compilers 3-4

#### CS 144
Introduction to Computer Networking 3-4

#### CS 284
Introduction to Computer Networks 3-4

#### CS 145
Introduction to Databases 3-4

#### CS 148
Introduction to Computer Graphics and Imaging 3-4

#### CS 194W
Software Project (WIM) 3

### Electrical Engineering (EE) Minor

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

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

<table>
<thead>
<tr>
<th>Units</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>ENGR 40 Introductory Electronics</td>
</tr>
<tr>
<td></td>
<td>ENGR 40N Engineering Wireless Networks</td>
</tr>
<tr>
<td></td>
<td>ENGR 40P Physics of Electrical Engineering</td>
</tr>
</tbody>
</table>

Select one of the following options:

**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 108A Digital Systems I
- EE 108B Digital Systems II

In addition, four letter-graded EE or cognate courses at the 100-level or higher must be taken (12 units minimum)

### 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. Skill in using modern computing facilities is essential for electrical engineers, and an increasing number of courses routinely require it. This skill should be acquired early in the program, either by taking one of the regular computer science courses or by self-study.

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, or it may serve as the first step in graduate work leading to the degree of Engineer or Ph.D. 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).

Students working toward the Master of Science degree in Electrical Engineering who are considering a Ph.D. or Engineer degree program in Electrical Engineering at Stanford must request the addition of a new degree program by submitting a Graduate Program Authorization Petition in Axess for approval by the department. The petition must be submitted and approved at least one quarter prior to M.S. degree completion. Once the M.S. degree in EE has been conferred, a student may not register for additional course work without this approval.

Students originally admitted only to the M.S. degree may petition the EE Graduate Admissions Committee during autumn quarter of their second year at Stanford for a change of status to the Ph.D. program with permission to take the Ph.D. qualifying exam in January. Requirements for the petition include a grade point average of 3.5 on Stanford courses and a written statement of academic and financial support from an EE faculty member with whom the student has conducted preliminary research through directed reading (EE 390 Special Studies or Projects in Electrical Engineering or EE 391 Special Studies and Reports in Electrical Engineering) or as part of a 300-level project course. Decisions are based on performance and the strength of the support letter.

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.

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 graduate 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 graduate students. For more information regarding the Honors Cooperative Program, see the “School of Engineering” section of this bulletin.

Engineer Degree in Electrical Engineering

The Engineer degree is intended for those who desire more graduate training than can be obtained in a Master of Science Program. It differs from the Ph.D. primarily in looking toward professional engineering work rather than toward theoretical research or university teaching. The Engineer degree is normally awarded at the completion of a comprehensive two-year program of graduate study.

The Engineer degree requires a minimum of 90 units. Students may count up to 45 units completed at Stanford towards a master’s degree in an Engineering discipline or a relevant M.S. degree completed elsewhere toward the 90 units. Students who completed an M.S. at another institution must complete the Application for Graduate Residency Credit form and submit it to the Registrar’s Office for evaluation.

Applicants currently working toward the Stanford M.S. degree in Electrical Engineering must request permission to continue graduate studies beyond the master’s degree by submitting the Graduate Program Authorization Petition in Axess.
The student and thesis adviser jointly develop a course program, which must be approved by the adviser and then submitted to the department for approval. The Engineer thesis adviser must be an EE faculty member. The Application for Candidacy for Engineer Degree form must be submitted by the end of the second quarter in the program (fourth quarter for Honors Cooperative Program students). It is signed by the student, program adviser and thesis adviser, then approved by the department chair.

The equivalent of at least one quarter is devoted to independent study and thesis work with faculty guidance. The thesis is typically a professional report on the solution of a design problem.

The following requirements assume that the student has completed the requirements for the M.S. degree either at Stanford or elsewhere. The course requirements in addition to the M.S. Degree (or an equivalent amount of graduate work) are as follows:

Total of 45 units beyond the M.S. Degree:

- 6 units of lecture courses* in EE (or related courses in EE (cognates)), at the 300 level or higher, taken for a letter grade
- 21 units of lecture courses* in EE (or related courses in EE (cognates)), at the 200 level or higher, taken for a letter grade
- 3 units of lecture courses* at the 100 level or higher, taken for a letter grade
- 6-15 Thesis units (EE 400) taken with the Engineer thesis advisor

*Lecture courses do not include special studies (EE 390/391) and thesis (EE 400)

Additional units taken may include other math/science/engineering courses, seminars, research courses, and courses taken for CR/NC. All courses must be at the 100 level or higher.

Students must maintain a minimum GPA of 3.00 to continue candidacy for and receive the Engineer degree.

Some deviation from the above may be approved, but applications for such deviations should include a statement to support them, which is approved by the student’s program adviser and thesis adviser.

Students must review the Directions for Preparing Theses on the Registrar’s Office website before preparing the write-up of their thesis work for submission.

**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, and may also, with the support of an EE faculty member, be allowed to switch to the Engineer degree.

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. One of the two faculty members must have either a full, joint or courtesy appointment in the Electrical Engineering department. Students are expected 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 may 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 Cognate 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 the most recent information, see 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 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.


**Associate Professor** Bruce L. Lusignan;


**Chair:** Mark Horowitz

**Vice Chairs:** Robert W. Dutton, Dwight G. Nishimura, Benjamin Van Roy

**Associate Chair (Admissions):** Howard Zebker

**Chair (Academic Affairs Committee):** Dwight G. Nishimura


Assistant Professors: Amin Arbabian, Audrey Ellerbee, Sachin Katti, Philip Levis, Ayfer Ozgur Aydin, Ada Poon

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


Courtesy Associate Professors: Kwabena Boahen, Ron Fedkiw, Ramesh Johari, Hari Manoharan, David Mazieres, Michael McConnell, Andrew Ng, David Sanger, Daniel Spielman, Barbara van Schewick

Courtesy Assistant Professors: Sigrid Close, Surya Ganguli, Kerwyn C. Huang, David Liang, Ram Rajagopal, Amin Saberi

Lecturers: Dennis Allison, Craig Burkhart, Andrew Freeman, Wendy Ju, My Le, Roger Melen, Aneesh Nainani, David Obershaw, Dan O’Neill, Dinesh Patil, John Provine, David Sirkin, Jason Stinson, James Weaver


Consulting Associate Professors: Yang Lu, Micah Siegel, Jatinder Singh, Katelijn Vleugels, Jun Ye

Consulting Assistant Professor: Tejes Krishnamohan

Visiting Professors: David Allstot, Michael Black, Israel Cidon, Yonina Eldar, Jinyi Qi, Sandip Tiwari, David Tse, Zhipeing Yu

Visiting Associate Professors: Yong Guo, Kyesan Lee, Jie Lin, Maneesh Sahani, Dongwoo Yang

Visiting Assistant Professors: Prabal Dutta, Ofer Levi, Haim Permuter, Peter Vajda

* recalled to active duty