ELECTRICAL ENGINEERING


The Department of Electrical Engineering (EE) at Stanford innovates by conducting fundamental and applied research to develop physical technologies, hardware and software systems, and information technologies; it educates future academic and industry leaders; and it prepares students for careers in industry, academia, and research labs.

Electrical Engineering has effected societal changes at the heart of the information revolution. All forms of electrical and electronic devices—both hardware and software—are a part of daily lives, whether these are in the home, personal devices, or the infrastructures of communications, information, and computation. Electrical engineers use theories and tools from mathematics and physics to develop systems ranging from smart electric grids, wired and wireless communications and networking, embedded systems, integrated electronics, imaging and sensing devices, to Internet-based information technology.

The Electrical Engineering Department offers the following degrees: Bachelor of Science, Master of Science, and Doctor of Philosophy. The department also offers joint degrees in Electrical Engineering and Law (M.S./J.D.) and Electrical Engineering and Business Administration (M.S./M.B.A.). A minor can be obtained for the Bachelor of Science and Doctor of Philosophy.

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 disciplinary areas beyond the core, including hardware and software, information systems and science, and physical technology and science, as well as electives in multidisciplinary areas, including bio-electronics 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 disciplinary area, currently including hardware and software, information systems and science, and physical technology and science.

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.

Graduate Programs in Electrical Engineering

University regulations governing the M.S. and Ph.D. degrees are described in the “Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)” 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.

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 Circuits, Software and Hardware Systems, Communications and Networking, Physical Technology and Science, and Signal Processing, Control and Optimization.

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.

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 information.
Disciplinary Areas in Electrical Engineering

Electrical Engineering spans a diverse set of intellectual disciplines and applications. The disciplines can be grouped into three overlapping and interrelated areas:

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

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

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

Multidisciplinary Research

EE faculty collaborate with researchers from other departments and schools across campus. While the main applications of electrical engineering in the past four decades have been in information technology, EE tools and techniques are being increasingly applied more broadly to address major societal problems in areas such as:

Biomedical
Research in the biomedical area utilizes engineering approaches to meet the unmet needs in diagnosis, staging, treatment, and mitigation of illnesses including cancer, diabetes, heart diseases, as well as brain disorders. Lower-cost, prevention-oriented health care delivery is critically needed, as well as new approaches to previously untreatable health conditions. Addressing these challenges requires discovering and creating fundamentally new devices and systems for critical diagnostics (sensors, imaging), therapeutic (lasers, pacemakers, and neural interfaces), and analytical (high-throughput sequencing, healthcare IT) technologies.

Energy
Research in energy is motivated at the macro level by the rapid rise in worldwide demand for electricity and the threat of global climate change and on the micro level by the explosion in the number of mobile devices and sensors whose performance and lifetimes are limited by energy.

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

Electrical Engineering Course Catalog Numbering System

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

<table>
<thead>
<tr>
<th>Number</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>010-099</td>
<td>first or second year undergraduate</td>
</tr>
<tr>
<td>100-199</td>
<td>second through fourth year</td>
</tr>
<tr>
<td>200-299</td>
<td>undergraduate</td>
</tr>
<tr>
<td>300-399</td>
<td>mezzanine courses for advanced</td>
</tr>
<tr>
<td></td>
<td>undergraduate or first-year graduate</td>
</tr>
<tr>
<td>400-499</td>
<td>second through fourth year</td>
</tr>
<tr>
<td></td>
<td>graduate</td>
</tr>
<tr>
<td>600-799</td>
<td>special courses for advanced</td>
</tr>
<tr>
<td></td>
<td>graduate</td>
</tr>
<tr>
<td></td>
<td>special summer courses</td>
</tr>
</tbody>
</table>

Undergraduate Programs in Electrical Engineering

To major in Electrical Engineering (EE), undergraduates should follow the requirements below. Students must have a program planning sheet approved by their adviser and the department once 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 last quarter of senior year. Program sheets are available at http://ughb.stanford.edu. Students must receive at least a 2.0 grade point average (GPA) in courses taken for the EE major; all classes must be taken for a letter grade.

Students interested in a minor should consult the "Minor in Electrical Engineering (p. 6)" tab of this section of this bulletin.

A Stanford undergraduate may work simultaneously toward the B.S. and M.S. degrees. See the Master’s tab (p. 6) of this section of the bulletin.

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 disciplinary areas beyond the core, including hardware and software, information systems and science, and physical technology and science, as well as electives in multidisciplinary areas, including bioelectronics 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

Select one sequence: May also be satisfied with AP Calculus.

MATH 19 & MATH 20 & MATH 21
Calculus and Calculus and Calculus

Select one 2-course sequence:

CME 100 & CME 102
Vector Calculus for Engineers and Ordinary Differential Equations for Engineers (Same as ENGR 154 and ENGR 155A)

MATH 51 & MATH 53
Linear Algebra, Multivariable Calculus, and Modern Applications and Ordinary Differential Equations with Linear Algebra

EE Math. One additional 100-level course. Select one: EE 103
Introduction to Matrix Methods (Preferred)

MATH 113
Linear Algebra and Matrix Theory

CS 100
Mathematical Foundations of Computing

Statistics/Probability. Select one:

EE 178
Probabilistic Systems Analysis (Preferred)

CS 109
Introduction to Probability for Computer Scientists

Science

Minimum 12 units

Select one sequence:

PHYSICS 41 & EE 42
Mechanics and Introduction to Electromagnetics and Its Applications

PHYSICS 41 & PHYSICS 43
Mechanics and Electricity and Magnetism

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 4-2.

Technology in Society

One course, see Basic Requirement 4 in the School of Engineering section. The course taken must be on the School of Engineering Approved Courses list, Fig 4-3, the year it is taken.

Engineering Topics

Minimum 60 units comprised of: Engineering Fundamentals (minimum 10 units), Core Electrical Engineering Courses (minimum 16 units) Disciplinary Area (minimum 17 units), Electives (maximum 17 units, restrictions apply).

Engineering Fundamentals

2 courses required; minimum 10 units

Select one:

CS 106B/ENGR 70B or CS 106X/ENGR 70X
Programming Abstractions or Programming Abstractions (Accelerated)

Choose one Fundamental from the Approved List; Recommended: ENGR 40A and ENGR 40B or ENGR 40M (recommended before taking EE 101A); taking CS 106A or a second ENGR 40-series course not allowed for the Fundamentals elective. Choose from table in Undergraduate Handbook, Approved List.

Core Electrical Engineering Courses

EE 100 The Electrical Engineering Profession
EE 101A Circuits I

EE 102A Signal Processing and Linear Systems I
EE 108 Digital System Design
EE 65 Modern Physics for Engineers
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 157 Virtual Reality (WIM/Design)
EE 168 Introduction to Digital Image Processing (WIM/Design)
EE 191W Special Studies and Reports in Electrical Engineering (WIM; Department approval required)
EE 264W Digital Signal Processing (WIM/Design)
EE 267W Virtual Reality (WIM/Design)
CS 194W Software Project (WIM/Design)

Design Course

Select one. Students may select their Design course from any Disciplinary Area.

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 157 Virtual Reality (WIM/Design)
EE 168 Introduction to Digital Image Processing (WIM/Design)
EE 262 Two-Dimensional Imaging (Design)
EE 264 Digital Signal Processing (Design)
EE 264W Digital Signal Processing (WIM/Design)
EE 267 Virtual Reality (Design)
EE 267W Virtual Reality (WIM/Design)
CS 194 Software Project (Design)
CS 194W Software Project (WIM/Design)

Electives

Minimum 17 units. The elective units should be sufficient to meet the 60 unit total for the major, over and above the 40 units of Math and Science. Depending on units completed in the Disciplinary Area, elective units will be in the range of 17 units or less. Students may select electives from the disciplinary areas; from the multidisciplinary elective areas; or any combination of disciplinary and multidisciplinary areas. May include up to two additional Engineering Fundamentals, any CS 193 course and any letter graded EE courses (minus any previously noted restrictions). Freshman and Sophomore seminars, EE 191 and CS 106A do not count toward the 60 units. Students may have fewer elective units if they have more units in their disciplinary area.

1 Math 41 and Math 42 are no longer offered and have been replaced by MATH 19, MATH 20, and MATH 21. If used for math, EE 103 may not be used as an EE disciplinary elective. PHYSICS 41E may be used in place of PHYSICS 41.

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Disciplinary Areas

<table>
<thead>
<tr>
<th>Hardware and Software</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 103 Introduction to Matrix Methods</td>
<td>3-5</td>
</tr>
<tr>
<td>EE 104 Introduction to Machine Learning</td>
<td>3-5</td>
</tr>
<tr>
<td>EE 180 Digital Systems Architecture (Required)</td>
<td>4</td>
</tr>
<tr>
<td>EE 107 Embedded Networked Systems</td>
<td>3</td>
</tr>
<tr>
<td>EE 109 Digital Systems Design Lab (WIM/Design)</td>
<td>4</td>
</tr>
<tr>
<td>EE 118 Introduction to Mechatronics</td>
<td>4</td>
</tr>
<tr>
<td>EE 155 Green Electronics (Design)</td>
<td>4</td>
</tr>
<tr>
<td>EE 264 Digital Signal Processing (Design)</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 264W Digital Signal Processing (WIM/Design)</td>
<td>5</td>
</tr>
<tr>
<td>EE 267 Virtual Reality (Design)</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 267W Virtual Reality (WIM/Design)</td>
<td>5</td>
</tr>
<tr>
<td>EE 271 Introduction to VLSI Systems</td>
<td>3</td>
</tr>
<tr>
<td>EE 272 Design Projects in VLSI Systems</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 273 Digital Systems Engineering</td>
<td>3</td>
</tr>
<tr>
<td>EE 282 Computer Systems Architecture</td>
<td>3</td>
</tr>
<tr>
<td>EE 285 Embedded Systems Workshop</td>
<td>2</td>
</tr>
<tr>
<td>CS 107 Computer Organization and Systems (Required prerequisite for EE 180; CS 107E preferred)</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 108 Object-Oriented Systems Design</td>
<td>3-4</td>
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<tr>
<td>CS 110 Principles of Computer Systems</td>
<td>3-5</td>
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<tr>
<td>CS 131 Computer Vision: Foundations and Applications</td>
<td>3-4</td>
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<tr>
<td>CS 140 Operating Systems and Systems Programming</td>
<td>3-4</td>
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<tr>
<td>CS 143 Compilers</td>
<td>3-4</td>
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<tr>
<td>CS 144 Introduction to Computer Networking</td>
<td>3-4</td>
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<tr>
<td>CS 145 Data Management and Data Systems</td>
<td>3-4</td>
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<tr>
<td>CS 148 Introduction to Computer Graphics and Imaging</td>
<td>3-4</td>
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<tr>
<td>CS 149 Parallel Computing</td>
<td>3-4</td>
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<tr>
<td>CS 155 Computer and Network Security</td>
<td>3</td>
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<tr>
<td>CS 194W Software Project (WIM/Design)</td>
<td>3</td>
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<tr>
<td>CS 221 Artificial Intelligence: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 223A Introduction to Robotics</td>
<td>3</td>
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<tr>
<td>CS 224N Natural Language Processing with Deep Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 225A Experimental Robotics</td>
<td>3</td>
</tr>
<tr>
<td>CS 229 Machine Learning</td>
<td>3-4</td>
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<tr>
<td>CS 231A Computer Vision: From 3D Reconstruction to Recognition</td>
<td>3-4</td>
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<tr>
<td>CS 231N Convolutional Neural Networks for Visual Recognition</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 241 Embedded Systems Workshop</td>
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<tr>
<td>CS 244 Advanced Topics in Networking</td>
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<tr>
<td>Information Systems and Science</td>
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<tr>
<td>EE 102B Signal Processing and Linear Systems II (Required)</td>
<td>4</td>
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<tr>
<td>EE 103 Introduction to Matrix Methods</td>
<td>3-5</td>
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<tr>
<td>EE 104 Introduction to Machine Learning</td>
<td>3-5</td>
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<tr>
<td>EE 107 Embedded Networked Systems</td>
<td>3</td>
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<tr>
<td>EE 118 Introduction to Mechatronics</td>
<td>4</td>
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<tr>
<td>EE 124 Introduction to Neuroelectrical Engineering</td>
<td>3</td>
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<tr>
<td>EE 133 Analog Communications Design Laboratory (WIM/Design)</td>
<td>3-4</td>
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<tr>
<td>EE 155 Green Electronics (WIM/Design)</td>
<td>4</td>
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<tr>
<td>EE 168 Introduction to Digital Image Processing (WIM/Design)</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 169 Introduction to Bioimaging</td>
<td>3</td>
</tr>
<tr>
<td>EE 179 Analog and Digital Communication Systems</td>
<td>3</td>
</tr>
<tr>
<td>EE 261 The Fourier Transform and Its Applications</td>
<td>3</td>
</tr>
<tr>
<td>EE 262 Two-Dimensional Imaging (Design)</td>
<td>3</td>
</tr>
<tr>
<td>EE 263 Introduction to Linear Dynamical Systems</td>
<td>3</td>
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<tr>
<td>EE 264 Digital Signal Processing (Design)</td>
<td>3-4</td>
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<tr>
<td>EE 264W Digital Signal Processing (WIM/Design)</td>
<td>5</td>
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<tr>
<td>EE 267 Virtual Reality (Design)</td>
<td>3-4</td>
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<tr>
<td>EE 267W Virtual Reality (WIM/Design)</td>
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<tr>
<td>EE 278 Introduction to Statistical Signal Processing</td>
<td>3</td>
</tr>
<tr>
<td>EE 279 Introduction to Digital Communication</td>
<td>3</td>
</tr>
<tr>
<td>CS 107 Computer Organization and Systems</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 229 Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>ENGR 105 Feedback Control Design</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 205 Introduction to Control Design Techniques</td>
<td>3</td>
</tr>
<tr>
<td>Physical Technology and Science</td>
<td></td>
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<tr>
<td>EE 101B Circuits II (Required)</td>
<td>4</td>
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<tr>
<td>EE 103 Introduction to Matrix Methods</td>
<td>3-5</td>
</tr>
<tr>
<td>EE 107 Embedded Networked Systems</td>
<td>3</td>
</tr>
<tr>
<td>EE 114 Fundamentals of Analog Integrated Circuit Design</td>
<td>3-4</td>
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<tr>
<td>EE 116 Semiconductor Devices for Energy and Electronics</td>
<td>3</td>
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<tr>
<td>EE 118 Introduction to Mechatronics</td>
<td>4</td>
</tr>
<tr>
<td>EE 124 Introduction to Neuroelectrical Engineering</td>
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<tr>
<td>EE 133 Analog Communications Design Laboratory (WIM/Design)</td>
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<tr>
<td>EE 134 Introduction to Photonics (WIM/Design)</td>
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<tr>
<td>EE 142 Engineering Electromagnetics</td>
<td>3</td>
</tr>
<tr>
<td>EE 153 Power Electronics (WIM/Design)</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 155 Green Electronics (WIM/Design)</td>
<td>4</td>
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</tbody>
</table>
EE 212 Integrated Circuit Fabrication Processes  3
EE 214B Advanced Integrated Circuit Design  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
EE 264 Digital Signal Processing (Design)  3-4
EE 264W Digital Signal Processing (WIM/Design)  5
EE 267 Virtual Reality (Design)  3-4
EE 267W Virtual Reality (WIM/Design)  5
EE 271 Introduction to VLSI Systems  3
EE 272 Design Projects in VLSI Systems  3-4
EE 273 Digital Systems Engineering  3
EE 282 Computer Systems Architecture  3
CS 107 Computer Organization and Systems  3-5
ENGR 105 Feedback Control Design  3

**Multidisciplinary Area Electives**

**Bio-electronics and Bio-imaging**

EE 101B Circuits II  4
EE 102B Signal Processing and Linear Systems II  4
EE 107 Embedded Networked Systems  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 225 Biochips and Medical Imaging  3
BIOE 248 Neuroengineering Laboratory  3
BIOE 131 Ethics in Bioengineering  3
MED 275B Biodesign Fundamentals  4

**Energy and Environment**

EE 101B Circuits II  4
EE 103 Introduction to Matrix Methods  3-5
EE 116 Semiconductor Devices for Energy and Electronics  3
EE 134 Introduction to Photonics (WIM/Design)  4
EE 151 Sustainable Energy Systems  3
EE 153 Power Electronics (WIM/Design)  3-4
EE 155 Green Electronics (WIM/Design)  4
EE 168 Introduction to Digital Image Processing (WIM/Design)  3-4
EE 180 Digital Systems Architecture  4
EE 263 Introduction to Linear Dynamical Systems  3
EE 293 Energy storage and conversion: Solar Cells, Fuel Cells, Batteries and Supercapacitors  3-4
EE 293B Fundamentals of Energy Processes  3
CEE 107A Understanding Energy (Formerly CEE 173A)  3-5
CEE 155 Introduction to Sensing Networks for CEE  3-4
CEE 176A Energy Efficient Buildings  3-4
CEE 176B 100% Clean, Renewable Energy and Storage for Everything  3-4
ENGR 105 Feedback Control Design  3
ENGR 205 Introduction to Control Design Techniques  3
MATSCI 142 Quantum Mechanics of Nanoscale Materials (Formerly MATSCI 157)  4
MATSCI 152 Electronic Materials Engineering  4
MATSCI 156 Solar Cells, Fuel Cells, and Batteries: Materials for the Energy Solution  3-4
ME 185 Electric Vehicle Design  3
ME 227 Vehicle Dynamics and Control  3
ME 271E Aerial Robot Design  4

**Music**

EE 102B Signal Processing and Linear Systems II  4
EE 109 Digital Systems Design Lab (WIM/Design)  4
EE 264 Digital Signal Processing (Design)  3-4
EE 264W Digital Signal Processing (WIM/Design)  5
MUSIC 250A Physical Interaction Design for Music  3-4
MUSIC 256A Music, Computing, Design I: The Art of Design  3-4
MUSIC 256B Music, Computing, Design II: Virtual and Augmented Reality for Music  3-4
MUSIC 257 Neuroplasticity and Musical Gaming  3-5
MUSIC 320 Introduction to Audio Signal Processing  2-4
MUSIC 420A Signal Processing Models in Musical Acoustics  1
MUSIC 421A Time-Frequency Audio Signal Processing  1
MUSIC 422 Perceptual Audio Coding  3
MUSIC 424 Signal Processing Techniques for Digital Audio Effects  3-4

1 Best taken as a coterm student.

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 adviser 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 DegreeProgress 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:

<table>
<thead>
<tr>
<th>Option</th>
<th>Units</th>
<th>Courses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option I</td>
<td>8</td>
<td>EE 101A Circuits I, EE 101B Circuits II</td>
</tr>
<tr>
<td>Option II</td>
<td>5</td>
<td>EE 102A Signal Processing and Linear Systems I, EE 102B Signal Processing and Linear Systems II</td>
</tr>
<tr>
<td>Option III</td>
<td>6</td>
<td>EE 102A Signal Processing and Linear Systems I, EE 103 Introduction to Matrix Methods</td>
</tr>
<tr>
<td>Option IV</td>
<td>6</td>
<td>EE 108 Digital System Design, EE 180 Digital Systems Architecture</td>
</tr>
</tbody>
</table>

In addition, four letter-graded EE 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.

**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 are 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 Officer before the end of the first quarter of graduate study (second quarter for Honors Cooperative Program students); a final revised version is due at the beginning of 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 quarter graduate 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 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 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 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 (M.S./J.D.)

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 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.

See the EE Graduate Handbook (https://stanford.box.com/s/dhub4flfcupj49zn1k9bp8y57197bp) for more information about the joint degree programs.

Doctor of Philosophy in Electrical Engineering

The University requirements for the Ph.D. degree are described in the “Graduate Degrees (http://exploredegrees.stanford.edu/graduatedegrees)” 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 (https://ee.stanford.edu/academics/graduate-degree-progress/quals). Students are required to pass the qualifying exam prior to the end of winter quarter of their second year of study. Students who have never taken the qualifying examination or have not passed the qualifying exam 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 either have a full or joint 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. Such students may be allowed to complete a master's degree in Electrical Engineering instead.

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

For complete requirements and additional information, see the department’s web site (https://ee.stanford.edu/academics/graduate-degree-progress).

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 courses (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.

Graduate Advising Expectations

The Department of Electrical Engineering is committed to providing academic advising in support of graduate student scholarly and professional development. When most effective, this advising relationship entails collaborative and sustained engagement by both the adviser and the advisee. As a best practice, advising expectations...
should be periodically discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity.

Faculty advisers guide students in key areas such as selecting courses, designing and conducting research, developing of teaching pedagogy, navigating policies and degree requirements, and exploring academic opportunities and professional pathways.

Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program.

For a statement of University policy on graduate advising, see the "Graduate Advising" section of this bulletin.


Chair: Stephen Boyd

Associate Chairs: Robert W. Dutton (Undergraduate Education), Fouad Tobagi (Graduate Education), Howard Zebker (Admissions)

Academic Affairs Committee Chair: Professor Joseph M. Kahn


Associate Professors: Dawson Engler, Sachin Katti, Philip Levis, Ada Poon, Eric Pop

Assistant Professors: Amin Arbabian, John Duchi, Jonathan Fan, Ayfer Ozgur Aytin, Mert Pilanci, Priyanka Raina, Juan Rivas, Dorsa Sadigh, Gordon Wetzstein, Mary Wootters

Professors (Research): William J. Dally, Butrus Khuri-Yakub, Piero Pianetta


Courtesy Associate Professors: Mohsen Bayati, Sigrid Close, Ramesh Johari, Jin Hyung Lee, Ram Rajagopal, Amin Saberi

Lecturers: Dennis Allison, Raul Camposano, Jonathan Candelaria, Andrea Di Blas, Antun Domic, Abbas Emami-Naeini, Leslie Field, J. Andrew Freeman, Timothy Gould, Patrick Groeneveld, My T. Le, Scott Murray, David Obershaw, Dan O’Neill, Ronald Quan, Jatinder Singh, Jason Stinson, James Weaver

Adjunct Professors: Ahmad Bahai, Rick Bahr, David Bloom, Fred M. Gibbons, Dimitry Gorinevsky, Bob S. Hu, Theodore Kamins, Fred Kish, David Leeson, Georgios Michelogiannakis, Fernando Mujica, Reza Nasiri Mahalati, Stephen Ryu, Ronald Schafer, Ashok Srivastava, David Sussillo, John Wenstrand, Sebastian Thrun

Visiting Professor: Wei-Zen Chen

Visiting Associate Professor: Matthew Gilbert