ELECTRICAL ENGINEERING UNDERGRADUATE MAJOR

See the "Department of Electrical Engineering (http://exploreddegrees.stanford.edu/schoolofengineering/electricalengineering)" section of this bulletin for additional information on the department, and its programs and faculty.

The department offers a B.S. as well as a minor in Electrical Engineering.

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 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.

Requirements

<table>
<thead>
<tr>
<th>Mathematics</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Select one sequence: May also be satisfied with AP Calculus.</td>
<td>10</td>
</tr>
<tr>
<td>MATH 19 &amp; MATH 20 &amp; MATH 21</td>
<td>Calculus and Calculus</td>
</tr>
<tr>
<td>Select one 2-course sequence:</td>
<td>10</td>
</tr>
<tr>
<td>CME 100 &amp; CME 102</td>
<td>Vector Calculus for Engineers and Ordinary Differential Equations for Engineers (Same as ENGR 154 and ENGR 155A)</td>
</tr>
<tr>
<td>MATH 51 &amp; MATH 53</td>
<td>Linear Algebra, Multivariable Calculus, and Modern Applications and Ordinary Differential Equations with Linear Algebra</td>
</tr>
<tr>
<td>EE Math. One additional 100-level course. Select one:</td>
<td>3</td>
</tr>
<tr>
<td>EE 103</td>
<td>Introduction to Matrix Methods (Preferred)</td>
</tr>
<tr>
<td>MATH 113</td>
<td>Linear Algebra and Matrix Theory</td>
</tr>
<tr>
<td>CS 103</td>
<td>Mathematical Foundations of Computing</td>
</tr>
<tr>
<td>Statistics/Probability. Select one:</td>
<td>3-4</td>
</tr>
<tr>
<td>EE 178</td>
<td>Probabilistic Systems Analysis (Preferred)</td>
</tr>
<tr>
<td>CS 109</td>
<td>Introduction to Probability for Computer Scientists</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Science</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Select one sequence:</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 41 &amp; EE 42</td>
<td>Mechanics and Introduction to Electromagnetics and Its Applications</td>
</tr>
<tr>
<td>PHYSICS 41 &amp; PHYSICS 43</td>
<td>Mechanics and Electricity and Magnetism</td>
</tr>
<tr>
<td>PHYSICS 61 &amp; PHYSICS 63</td>
<td>Mechanics and Special Relativity and Electricity, Magnetism, and Waves</td>
</tr>
<tr>
<td>Science elective. One additional 4-5 unit course from approved list in Undergraduate Handbook, Figure 4-2.</td>
<td>4-5</td>
</tr>
<tr>
<td>Technology in Society</td>
<td>3-5</td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 106B</td>
<td>Programming Abstractions</td>
</tr>
<tr>
<td>or CS 106X</td>
<td>Programming Abstractions</td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

Core Electrical Engineering Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 100</td>
<td>The Electrical Engineering Profession</td>
</tr>
<tr>
<td>EE 101A</td>
<td>Circuits I</td>
</tr>
<tr>
<td>EE 102A</td>
<td>Signal Processing and Linear Systems I</td>
</tr>
<tr>
<td>EE 108</td>
<td>Digital System Design</td>
</tr>
<tr>
<td>EE 65</td>
<td>Modern Physics for Engineers</td>
</tr>
</tbody>
</table>

Physics of Electrical Engineering.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 109</td>
<td>Digital Systems Design Lab (WIM/Design)</td>
</tr>
<tr>
<td>EE 133</td>
<td>Analog Communications Design Laboratory (WIM/Design)</td>
</tr>
<tr>
<td>EE 134</td>
<td>Introduction to Photonics (WIM/Design)</td>
</tr>
<tr>
<td>EE 153</td>
<td>Power Electronics (WIM/Design)</td>
</tr>
<tr>
<td>EE 155</td>
<td>Green Electronics (WIM/Design)</td>
</tr>
<tr>
<td>EE 168</td>
<td>Introduction to Digital Image Processing (WIM/Design)</td>
</tr>
<tr>
<td>EE 191W</td>
<td>Special Studies and Reports in Electrical Engineering (WIM; Department approval required)</td>
</tr>
<tr>
<td>EE 264W</td>
<td>Digital Signal Processing (WIM/Design)</td>
</tr>
<tr>
<td>EE 267W</td>
<td>Virtual Reality (WIM/Design)</td>
</tr>
<tr>
<td>CS 194W</td>
<td>Software Project (WIM/Design)</td>
</tr>
</tbody>
</table>

Writing in the Major (WIM)

Select one. A single course can concurrently meet the WIM and Design Requirements.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 109</td>
<td>Digital Systems Design Lab (WIM/Design)</td>
</tr>
<tr>
<td>EE 133</td>
<td>Analog Communications Design Laboratory (WIM/Design)</td>
</tr>
<tr>
<td>EE 134</td>
<td>Introduction to Photonics (WIM/Design)</td>
</tr>
<tr>
<td>EE 153</td>
<td>Power Electronics (WIM/Design)</td>
</tr>
<tr>
<td>EE 155</td>
<td>Green Electronics (WIM/Design)</td>
</tr>
<tr>
<td>EE 168</td>
<td>Introduction to Digital Image Processing (WIM/Design)</td>
</tr>
<tr>
<td>EE 191W</td>
<td>Special Studies and Reports in Electrical Engineering (WIM; Department approval required)</td>
</tr>
<tr>
<td>EE 264W</td>
<td>Digital Signal Processing (WIM/Design)</td>
</tr>
<tr>
<td>EE 267W</td>
<td>Virtual Reality (WIM/Design)</td>
</tr>
<tr>
<td>CS 194W</td>
<td>Software Project (WIM/Design)</td>
</tr>
</tbody>
</table>

Design Course

3-5
Disciplinary Area.

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 194 may be used in place 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 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.
2. MATH 52 may be taken in place of MATH 51. CME 102 can be taken in place of MATH 53.
3. EE 42 may be used in place of PHYSICS 43 (if not used in EE electives area). The EE introductory class ENGR 40A and ENGR 40B or ENGR 40M may be taken concurrently with either EE 42 or PHYSICS 43. There are no prerequisites for ENGR 40A and ENGR 40B or ENGR 40M.
4. For upper division students, a 200-level seminar in their disciplinary area will be accepted, on petition.
5. Students may petition to have either PHYSICS 65 or the combination of PHYSICS 45 and PHYSICS 70 count as an equivalent to EE 65.
6. 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.
7. To satisfy Design, must take EE 264 or EE 267 for 4 units and complete the laboratory project.
8. A course may only be counted towards one requirement; it may not be double-counted. All courses taken for the major must be taken for a letter grade if that option is offered by the instructor. Minimum Combined GPA for all courses in Engineering Fundamentals and Depth is 2.0.

Disciplinary Areas

<table>
<thead>
<tr>
<th>Units</th>
<th>Hardware and Software</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EE 103</td>
</tr>
<tr>
<td></td>
<td>EE 104</td>
</tr>
</tbody>
</table>

Electives

17 units

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 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) |

EE 108 | Object-Oriented Systems Design | 3-4 |
CS 110 | Principles of Computer Systems | 3-5 |
CS 131 | Computer Vision: Foundations and Applications | 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 145 | Data Management and Data Systems | 3-4 |
CS 148 | Introduction to Computer Graphics and Imaging | 3-4 |
CS 149 | Parallel Computing | 3-4 |
CS 155 | Computer and Network Security | 3 |
CS 194W | Software Project (WIM/Design) | 3 |
CS 221 | Artificial Intelligence: Principles and Techniques | 3-4 |
CS 223A | Introduction to Robotics | 3 |
CS 224N | Natural Language Processing with Deep Learning | 3-4 |
CS 225A | Experimental Robotics | 3 |
CS 229 | Machine Learning | 3-4 |
CS 231A | Computer Vision: From 3D Reconstruction to Recognition | 3-4 |
CS 231N | Convolutional Neural Networks for Visual Recognition | 3-4 |
CS 241 | Embedded Systems Workshop | 3 |
CS 244 | Advanced Topics in Networking | 3-4 |

Information Systems and Science

EE 102B | Signal Processing and Linear Systems II (Required) | 4 |
EE 103 | Introduction to Matrix Methods | 3-5 |
EE 104 | Introduction to Machine Learning | 3-5 |
EE 107 | Embedded Networked Systems | 3 |
EE 118 | Introduction to Mechatronics | 3 |
EE 124 | Introduction to Neuroelectrical Engineering | 3-4 |
EE 133 | Analog Communications Design Laboratory (WIM/Design) | 3-4 |
EE 155 | Green Electronics (WIM/Design) | 3-4 |
EE 168 | Introduction to Digital Image Processing (WIM/Design) | 3-4 |
EE 169 | Introduction to Bioimaging | 3 |
EE 179  Analog and Digital Communication Systems  3
EE 261  The Fourier Transform and Its Applications  3
EE 262  Two-Dimensional Imaging (Design)  3
EE 263  Introduction to Linear Dynamical Systems  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 278  Introduction to Statistical Signal Processing  3
EE 279  Introduction to Digital Communication  3
CS 107  Computer Organization and Systems  3-5
CS 229  Machine Learning  3-4
ENGR 105  Feedback Control Design  3
ENGR 205  Introduction to Control Design Techniques  3

Physical Technology and Science

EE 101B  Circuits II (Required)  4
EE 103  Introduction to Matrix Methods  1  3-5
EE 107  Embedded Networked Systems  3
EE 114  Fundamentals of Analog Integrated Circuit Design  3-4
EE 116  Semiconductor Devices for Energy and Electronics  3
EE 118  Introduction to Mechatronics  4
EE 124  Introduction to Neuroengineering  3
EE 133  Analog Communications Design Laboratory (WIM/Design)  3-4
EE 134  Introduction to Photonics (WIM/Design)  4
EE 142  Engineering Electromagnetics  3
EE 153  Power Electronics (WIM/Design)  3-4
EE 155  Green Electronics (WIM/Design)  4
EE 212  Advanced Integrated Circuit Design  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 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
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 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  3-4
MUSIC 421A  Time-Frequency Audio Signal Processing  3-4
MUSIC 422  Perceptual Audio Coding  3
Honors Program in Electrical Engineering

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 advisor 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:

<table>
<thead>
<tr>
<th>Units</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Select one:</td>
</tr>
<tr>
<td>5</td>
<td>EE 42 Introduction to Electromagnetics and its Applications</td>
</tr>
<tr>
<td></td>
<td>EE 65 Modern Physics for Engineers</td>
</tr>
<tr>
<td></td>
<td>ENGR 40A &amp; ENGR 40B Introductory Electronics and Introductory Electronics Part II</td>
</tr>
<tr>
<td></td>
<td>ENGR 40M An Intro to Making: What is EE</td>
</tr>
<tr>
<td>8</td>
<td>Select one:</td>
</tr>
<tr>
<td></td>
<td>Option I:</td>
</tr>
<tr>
<td></td>
<td>EE 101A Circuits I</td>
</tr>
<tr>
<td></td>
<td>EE 101B Circuits II</td>
</tr>
<tr>
<td></td>
<td>Option II:</td>
</tr>
<tr>
<td></td>
<td>EE 102A Signal Processing and Linear Systems I</td>
</tr>
<tr>
<td></td>
<td>EE 102B Signal Processing and Linear Systems II</td>
</tr>
<tr>
<td></td>
<td>Option III:</td>
</tr>
<tr>
<td></td>
<td>EE 102A Signal Processing and Linear Systems I</td>
</tr>
<tr>
<td></td>
<td>EE 103 Introduction to Matrix Methods</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.