COMPUTER SCIENCE UNDERGRADUATE MAJOR

See the "Department of Computer Science (http://exploredegrees.stanford.edu/schoolofengineering/computerscience)" 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 Computer Science.

Computer Science (CS)

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

Mission of the Undergraduate Program in Computer Science

The mission of the undergraduate program in Computer Science is to develop students' breadth of knowledge across the subject areas of computer science, including their ability to apply the defining processes of computer science theory, abstraction, design, and implementation to solve problems in the discipline. Students take a set of core courses. After learning the essential programming techniques and the mathematical foundations of computer science, students take courses in areas such as programming techniques, automata and complexity theory, systems programming, computer architecture, analysis of algorithms, artificial intelligence, and applications. The program prepares students for careers in government, law, the corporate sector, and for graduate study.

Requirements

Mathematics (26 units minimum) –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 103</td>
</tr>
<tr>
<td>CS 109</td>
</tr>
<tr>
<td>MATH 19</td>
</tr>
<tr>
<td>MATH 20</td>
</tr>
<tr>
<td>MATH 21</td>
</tr>
<tr>
<td>Plus two electives</td>
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</tbody>
</table>

Science (11 units minimum) –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICS 41</td>
</tr>
<tr>
<td>or PHYSICS 41E</td>
</tr>
<tr>
<td>PHYSICS 43</td>
</tr>
<tr>
<td>Science elective</td>
</tr>
</tbody>
</table>

Technology in Society (3-5 units) –

| One course; course chosen must be on the SoE Approved Courses list at https://ughb.stanford.edu/ the year taken; see Basic Requirements 4 in the School of Engineering section |

Engineering Fundamentals (13 units minimum; see Basic Requirement 3 in the School of Engineering section) –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 106B</td>
</tr>
<tr>
<td>or CS 106X</td>
</tr>
<tr>
<td>ENGR 40M</td>
</tr>
</tbody>
</table>

Writing in the Major –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 181W</td>
</tr>
<tr>
<td>CS 191W</td>
</tr>
<tr>
<td>CS 194W</td>
</tr>
<tr>
<td>CS 210B</td>
</tr>
<tr>
<td>CS 294W</td>
</tr>
</tbody>
</table>

Computer Science Core (15 units) –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 107</td>
</tr>
<tr>
<td>or CS 107E</td>
</tr>
<tr>
<td>CS 110</td>
</tr>
<tr>
<td>CS 161</td>
</tr>
</tbody>
</table>

Senior Project (3 units) –

<table>
<thead>
<tr>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>CS 191</td>
</tr>
<tr>
<td>CS 191W</td>
</tr>
<tr>
<td>CS 194</td>
</tr>
<tr>
<td>CS 194H</td>
</tr>
<tr>
<td>CS 194W</td>
</tr>
<tr>
<td>CS 210B</td>
</tr>
<tr>
<td>CS 294</td>
</tr>
</tbody>
</table>

Computer Science Depth B.S.

Choose one of the following ten CS degree tracks (a track must consist of at least 25 units and 7 classes):

Artificial Intelligence Track –

<table>
<thead>
<tr>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 221</td>
</tr>
</tbody>
</table>

Select two courses, each from a different area:

Area I, AI Methods:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
</tr>
<tr>
<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
</tr>
</tbody>
</table>

Area II, Natural Language Processing:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 124</td>
<td>From Languages to Information</td>
</tr>
<tr>
<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
</tr>
<tr>
<td>CS 224S</td>
<td>Spoken Language Processing</td>
</tr>
<tr>
<td>CS 224U</td>
<td>Natural Language Understanding</td>
</tr>
</tbody>
</table>

Area III, Vision:
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 131</td>
<td>Computer Vision: Foundations and Applications</td>
</tr>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
</tr>
<tr>
<td>CS 231N</td>
<td>Convolutional Neural Networks for Visual Recognition</td>
</tr>
</tbody>
</table>

**Area IV, Robotics:**
- CS 223A: Introduction to Robotics
- CS 237A: Principles of Robot Autonomy I

Select one additional course from the Areas above or from the following:

**AI Methods:**
- CS 157: Computational Logic
- CS 205L: Continuous Mathematical Methods with an Emphasis on Machine Learning
- CS 230: Deep Learning
- CS 236: Deep Generative Models
- STATS 315A: Modern Applied Statistics: Learning
- STATS 315B: Modern Applied Statistics: Data Mining

**Comp Bio:**
- CS 235: Computational Methods for Biomedical Image Analysis and Interpretation
- CS 279: Computational Biology: Structure and Organization of Biomolecules and Cells
- CS 371: Computational Biology in Four Dimensions

**Information and the Web:**
- CS 276: Information Retrieval and Web Search
- CS 224W: Machine Learning with Graphs

**Other:**
- CS 151: Logic Programming
- CS 227B: General Game Playing
- CS 379: Interdisciplinary Topics (Offered occasionally)

**Robotics and Control:**
- CS 327A: Advanced Robotic Manipulation
- CS 329: Topics in Artificial Intelligence (with advisor approval)
- ENGR 205: Introduction to Control Design Techniques
- MS&E 251: Introduction to Stochastic Control with Applications
- MS&E 351: Dynamic Programming and Stochastic Control

**Track Electives:** at least three additional courses selected from the Areas and lists above, general CS electives, or the courses listed below. Students can replace one of these electives with a course found at https://cs.stanford.edu/explore.

Select one of the following:

- CS 221: Artificial Intelligence: Principles and Techniques
- CS 228: Probabilistic Graphical Models: Principles and Techniques
- CS 229: Machine Learning
- CS 231A: Computer Vision: From 3D Reconstruction to Recognition

Select one of the following:

- CS 235: Computational Methods for Biomedical Image Analysis and Interpretation
- CS 270: Modeling Biomedical Systems: Ontology, Terminology, Problem Solving
- CS 273A: The Human Genome Source Code
- CS 274: Representations and Algorithms for Computational Molecular Biology
- CS 275: Translational Bioinformatics
- CS 279: Computational Biology: Structure and Organization of Biomolecules and Cells

**Biocomputation Track—**

Unit requirements are non-standard for this track. See Handbook for Undergraduate Engineering Programs for details.

Select one of the following:

- CS 221: Artificial Intelligence: Principles and Techniques
- CS 228: Probabilistic Graphical Models: Principles and Techniques
- CS 229: Machine Learning
- CS 231A: Computer Vision: From 3D Reconstruction to Recognition

Select one of the following:

- CS 235: Computational Methods for Biomedical Image Analysis and Interpretation
- CS 270: Modeling Biomedical Systems: Ontology, Terminology, Problem Solving
- CS 273A: The Human Genome Source Code
- CS 274: Representations and Algorithms for Computational Molecular Biology
- CS 275: Translational Bioinformatics
- CS 279: Computational Biology: Structure and Organization of Biomolecules and Cells

One additional course from the lists above or the following:

- CS 124: From Languages to Information
- CS 145: Data Management and Data Systems
- CS 147: Introduction to Human-Computer Interaction Design
- CS 148: Introduction to Computer Graphics and Imaging
- CS 248: Interactive Computer Graphics

One course selected from the following:

- CS 108: Object-Oriented Systems Design
- CS 124: From Languages to Information
- CS 131: Computer Vision: Foundations and Applications
- CS 140: Operating Systems and Systems Programming
- or CS 140E: Operating systems design and implementation
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 142</td>
<td>Web Applications</td>
<td>3</td>
</tr>
<tr>
<td>CS 143</td>
<td>Compilers</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 144</td>
<td>Introduction to Computer Networking</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 145</td>
<td>Data Management and Data Systems</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 146</td>
<td>Introduction to Game Design and Development</td>
<td>3</td>
</tr>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 148</td>
<td>Introduction to Computer Graphics and Imaging</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 149</td>
<td>Parallel Computing</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 151</td>
<td>Logic Programming</td>
<td>3</td>
</tr>
<tr>
<td>CS 154</td>
<td>Introduction to Automata and Complexity Theory</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 155</td>
<td>Computer and Network Security</td>
<td>3</td>
</tr>
<tr>
<td>CS 157</td>
<td>Computational Logic</td>
<td>3</td>
</tr>
<tr>
<td>or PHIL 151</td>
<td>Metalogic</td>
<td>3</td>
</tr>
<tr>
<td>CS 166</td>
<td>Data Structures</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 168</td>
<td>The Modern Algorithmic Toolbox</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 190</td>
<td>Software Design Studio</td>
<td>3</td>
</tr>
<tr>
<td>CS 195</td>
<td>Supervised Undergraduate Research (4 units max)</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 205L</td>
<td>Continuous Mathematical Methods with an Emphasis on Machine Learning</td>
<td>3</td>
</tr>
<tr>
<td>CS 210A</td>
<td>Software Project Experience with Corporate Partners</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 217</td>
<td>Hardware Accelerators for Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 223A</td>
<td>Introduction to Robotics</td>
<td>3</td>
</tr>
<tr>
<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 224S</td>
<td>Spoken Language Processing</td>
<td>2-4</td>
</tr>
<tr>
<td>CS 224U</td>
<td>Natural Language Understanding</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 224W</td>
<td>Machine Learning with Graphs</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 225A</td>
<td>Experimental Robotics</td>
<td>3</td>
</tr>
<tr>
<td>CS 227B</td>
<td>General Game Playing</td>
<td>3</td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 229T</td>
<td>Statistical Learning Theory</td>
<td>3</td>
</tr>
<tr>
<td>CS 230</td>
<td>Deep Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 231A</td>
<td>Computer Vision: From 3D Reconstruction to Recognition</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 231N</td>
<td>Convolutional Neural Networks for Visual Recognition</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 232</td>
<td>Digital Image Processing</td>
<td>3</td>
</tr>
<tr>
<td>CS 233</td>
<td>Geometric and Topological Data Analysis</td>
<td>3</td>
</tr>
<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
<td>3</td>
</tr>
<tr>
<td>CS 235</td>
<td>Computational Methods for Biomedical Image Analysis and Interpretation</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 236</td>
<td>Deep Generative Models</td>
<td>3</td>
</tr>
<tr>
<td>CS 238</td>
<td>Decision Making under Uncertainty</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 240</td>
<td>Advanced Topics in Operating Systems</td>
<td>3</td>
</tr>
<tr>
<td>CS 242</td>
<td>Programming Languages</td>
<td>3</td>
</tr>
<tr>
<td>CS 243</td>
<td>Program Analysis and Optimizations</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 244</td>
<td>Advanced Topics in Networking</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 244B</td>
<td>Distributed Systems</td>
<td>3</td>
</tr>
<tr>
<td>CS 245</td>
<td>Principles of Data-Intensive Systems</td>
<td>3</td>
</tr>
<tr>
<td>CS 246</td>
<td>Mining Massive Data Sets</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 247</td>
<td>(Any suffix)</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 248</td>
<td>Interactive Computer Graphics</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 251</td>
<td>Cryptocurrencies and blockchain technologies</td>
<td>3</td>
</tr>
<tr>
<td>CS 252</td>
<td>Analysis of Boolean Functions</td>
<td>3</td>
</tr>
<tr>
<td>CS 254</td>
<td>Computational Complexity</td>
<td>3</td>
</tr>
<tr>
<td>CS 255</td>
<td>Introduction to Cryptography</td>
<td>3</td>
</tr>
<tr>
<td>CS 261</td>
<td>Optimization and Algorithmic Paradigms</td>
<td>3</td>
</tr>
<tr>
<td>CS 264</td>
<td>Beyond Worst-Case Analysis</td>
<td>3</td>
</tr>
<tr>
<td>CS 265</td>
<td>Randomized Algorithms and Probabilistic Analysis</td>
<td>3</td>
</tr>
<tr>
<td>CS 269I</td>
<td>(Not Given This Year)</td>
<td>3</td>
</tr>
<tr>
<td>CS 270</td>
<td>Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
<td>3</td>
</tr>
<tr>
<td>CS 272</td>
<td>Introduction to Biomedical Informatics Research Methodology</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 273A</td>
<td>The Human Genome Source Code</td>
<td>3</td>
</tr>
<tr>
<td>CS 273B</td>
<td>Deep Learning in Genomics and Biomedicine</td>
<td>3</td>
</tr>
<tr>
<td>CS 274</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 275</td>
<td>Translational Bioinformatics</td>
<td>4</td>
</tr>
<tr>
<td>CS 276</td>
<td>Information Retrieval and Search</td>
<td>3</td>
</tr>
<tr>
<td>CS 278</td>
<td>Social Computing</td>
<td>3</td>
</tr>
<tr>
<td>CS 279</td>
<td>Computational Biology: Structure and Organization of Biomolecules and Cells</td>
<td>3</td>
</tr>
<tr>
<td>CS 348B</td>
<td>Computer Graphics: Image Synthesis Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 348C</td>
<td>Computer Graphics: Animation and Simulation</td>
<td>3</td>
</tr>
<tr>
<td>CS 348K</td>
<td>Visual Computing Systems</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 371</td>
<td>Computational Biology in Four Dimensions</td>
<td>3</td>
</tr>
<tr>
<td>CME 108</td>
<td>Introduction to Scientific Computing</td>
<td>3</td>
</tr>
<tr>
<td>EE 180</td>
<td>Digital Systems Architecture</td>
<td>4</td>
</tr>
<tr>
<td>EE 263</td>
<td>Introduction to Linear Dynamical Systems</td>
<td>3</td>
</tr>
<tr>
<td>EE 282</td>
<td>Computer Systems Architecture</td>
<td>3</td>
</tr>
<tr>
<td>EE 364A</td>
<td>Convex Optimization I</td>
<td>3</td>
</tr>
<tr>
<td>BIOE 101</td>
<td>Systems Biology</td>
<td>3</td>
</tr>
<tr>
<td>MS&amp;E 152</td>
<td>Introduction to Decision Analysis</td>
<td>3-4</td>
</tr>
<tr>
<td>MS&amp;E 252</td>
<td>Decision Analysis: Foundations of Decision Analysis</td>
<td>3-4</td>
</tr>
<tr>
<td>STATS 206</td>
<td>Applied Multivariate Analysis</td>
<td>3</td>
</tr>
<tr>
<td>STATS 315A</td>
<td>Modern Applied Statistics: Learning</td>
<td>3</td>
</tr>
<tr>
<td>STATS 315B</td>
<td>Modern Applied Statistics: Data Mining</td>
<td>3</td>
</tr>
<tr>
<td>GENE 211</td>
<td>Genomics</td>
<td>3</td>
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<tr>
<td>One course from the following:</td>
<td>3-5</td>
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</tr>
<tr>
<td>CS 145</td>
<td>Data Management and Data Systems</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
<td>3-5</td>
</tr>
<tr>
<td>CS 221</td>
<td>Artificial Intelligence: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 228</td>
<td>Probabilistic Graphical Models: Principles and Techniques</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 235</td>
<td>Computational Methods for Biomedical Image Analysis and Interpretation</td>
<td>3-4</td>
</tr>
</tbody>
</table>
Computer Science Undergraduate Major

CS 270  Modeling Biomedical Systems: Ontology, Terminology, Problem Solving  3
CS 273A The Human Genome Source Code  3
CS 273B Deep Learning in Genomics and Biomedicine  3

CS 274  Representations and Algorithms for Computational Molecular Biology  3-4
CS 275  Translational Bioinformatics  4
CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
CS 373  Statistical and Machine Learning Methods for Genomics  3

EE 263  Introduction to Linear Dynamical Systems  3
EE 364A  Convex Optimization I  3
MS&E 152  Introduction to Decision Analysis  3-4
MS&E 252  Decision Analysis I: Foundations of Decision Analysis  3-4

STATS 206  Applied Multivariate Analysis  3
STATS 315A  Modern Applied Statistics: Learning  3
STATS 315B  Modern Applied Statistics: Data Mining  3
GENE 211  Genomics  3

One course selected from the list above or the following:
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
APPPHYS 294  Cellular Biophysics  3

BIO 104  Advanced Molecular Biology: Epigenetics and Proteostasis  5
BIO 118  (Not Given This Year)  4
BIO 214  Advanced Cell Biology  4
BIO 230  Molecular and Cellular Immunology  4
CHEM 141  The Chemical Principles of Life I  4

CHEM 171  Physical Chemistry I  4
BIOC 241  Biological Macromolecules  5

One course from the following:
BIOE 220  Introduction to Imaging and Image-based Human Anatomy  3
CHEMENG 150  Biochemical Engineering  3
CHEMENG 174  Environmental Microbiology I  3
CS 235  Computational Methods for Biomedical Image Analysis and Interpretation  3-4
CS 274  Representations and Algorithms for Computational Molecular Biology  3-4

CS 279  Computational Biology: Structure and Organization of Biomolecules and Cells  3
CS 371  Computational Biology in Four Dimensions  3
ME 281  Biomechanics of Movement  3
APPPHYS 294  Cellular Biophysics  3

BIO 104  Advanced Molecular Biology: Epigenetics and Proteostasis  5
BIO 112  Human Physiology  4
BIO 118  (Not Given This Year)  4
BIO 158  Developmental Neurobiology  4
BIO 183  Theoretical Population Genetics  3
BIO 214  Advanced Cell Biology  4
BIO 230  Molecular and Cellular Immunology  4
CHEM 171  Physical Chemistry I  4

BIOC 241  Biological Macromolecules  5
DBIO 210  Developmental Biology  4

GENE 211  Genomics  3
SURG 101  Regional Study of Human Structure  5

Computer Engineering Track—

For this track there is a 10 unit minimum for ENGR Fundamentals and a 29 unit minimum for Depth (for track and elective courses)

EE 108  Digital System Design  8
& EE 180  Digital Systems Architecture  8

Select two of the following:  8

EE 101A  Circuits I  4
EE 101B  Circuits II  4
EE 102A  Signal Processing and Linear Systems I  4
EE 102B  Signal Processing and Linear Systems II  4

Satisfy the requirements of one of the following concentrations:

1) Digital Systems Concentration

CS 140  Operating Systems and Systems Programming  3
or CS 140E or CS 140E or CS 140E  3

EE 109  Digital Systems Design Lab  8
EE 271  Introduction to VLSI Systems  8

Plus two of the following (6-8 units):

CS 140  Operating Systems and Systems Programming (if not counted above)  3
or CS 140E or CS 140E  3

CS 144  Introduction to Computer Networking  3
CS 149  Parallel Computing  4
CS 190  Software Design Studio  4

2) Robotics and Mechatronics Concentration

CS 205L  Continuous Mathematical Methods with an Emphasis on Machine Learning  3

CS 223A  Introduction to Robotics  3
ME 210  Introduction to Mechatronics  3
ENGR 105  Feedback Control Design  3

Plus one of the following (3-4 units):

CS 225A  Experimental Robotics  4
CS 231A  Computer Vision: From 3D Reconstruction to Recognition  4

ENGR 205  Introduction to Control Design Techniques  3
ENGR 207B  Linear Control Systems II  3

3) Networking Concentration

CS 140  Operating Systems and Systems Programming  3
& CS 144  Introduction to Computer Networking (CS 140E can substitute for CS 140)  3

Plus three of the following (9-11 units):

CS 240  Advanced Topics in Operating Systems  3
CS 241  Embedded Systems Workshop  3
CS 244  Advanced Topics in Networking  3
CS 244B  Distributed Systems  3
EE 179  Analog and Digital Communication Systems  3

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## Graphics Track—

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 205L</td>
<td>Continuous Mathematical Methods with an Emphasis on Machine Learning</td>
<td>3-5</td>
</tr>
<tr>
<td>CME 104</td>
<td>Linear Algebra and Partial Differential Equations for Engineers (Note: students taking CME 104 are also required to take its prerequisite course, CME 102)</td>
<td>3-5</td>
</tr>
<tr>
<td>CME 108</td>
<td>Introduction to Scientific Computing</td>
<td></td>
</tr>
<tr>
<td>MATH 52</td>
<td>Integral Calculus of Several Variables</td>
<td></td>
</tr>
<tr>
<td>MATH 113</td>
<td>Linear Algebra and Matrix Theory</td>
<td></td>
</tr>
</tbody>
</table>

Select one of the following: 5

- CS 205L
- CME 104
- CME 108
- MATH 52
- MATH 113

Select two of the following: 6-8

- CS 146
- CS 231A (or CS 131)
- CS 268
- CS 348A
- CS 348B
- CS 348C
- CS 348E
- CS 348K
- CS 448
- CS 142
- CS 146
- CS 148
- CS 194H
- CS 206
- CS 210A
- CS 278
- CS 347
- Any CS 377 "Topics in HCI" of three or more units
- CS 448B
- ARTSTUDI 160
- ARTSTUDI 162
- ARTSTUDI 163
- ARTSTUDI 164
- ARTSTUDI 165
- ARTSTUDI 166
- ARTSTUDI 168
- ARTSTUDI 172 (or COMM 272)
- ARTSTUDI 245
- COMM 121
- COMM 124
- COMM 154
- COMM 166
- COMM 172
- COMM 175
- COMM 176
- COMM 254
- COMM 324
- COMM 324
- ARTSTUDI 160
- ARTSTUDI 162
- ARTSTUDI 163
- ARTSTUDI 164
- ARTSTUDI 165
- ARTSTUDI 166
- ARTSTUDI 168
- ARTSTUDI 172
- ARTSTUDI 245
- PSYCH 30
- PSYCH 35
- PSYCH 45
- PSYCH 50
- PSYCH 60
- PSYCH 70
- PSYCH 75
- PSYCH 80
- PSYCH 90
- PSYCH 95

At least two additional courses from above list, the general CS electives list, or the following: 3-6

- Any d.school class of 3 or more units
- Any class of 3 or more units at hci.stanford.edu under the 'courses' link

## Human-Computer Interaction Track—

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 147</td>
<td>Introduction to Human-Computer Interaction Design</td>
<td>4</td>
</tr>
<tr>
<td>CS 247</td>
<td>(Any suffix)</td>
<td>4</td>
</tr>
</tbody>
</table>

Any three of the following:

- ARTSTUDI 160
- ARTSTUDI 162
- ARTSTUDI 163
- ARTSTUDI 164
- ARTSTUDI 165
- ARTSTUDI 166
- ARTSTUDI 168
- ARTSTUDI 172
- ARTSTUDI 245
- PSYCH 30
- PSYCH 35
- PSYCH 45
- PSYCH 50
- PSYCH 60
- PSYCH 70
- PSYCH 75
- PSYCH 80
- PSYCH 90
- PSYCH 95

Any of the following:

- PSYCH 30
- PSYCH 35
- PSYCH 45
- PSYCH 50
- PSYCH 60
- PSYCH 70
- PSYCH 75
- PSYCH 80
- PSYCH 90
- PSYCH 95
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMM 314</td>
<td>Ethnographic Methods</td>
</tr>
<tr>
<td>MS&amp;E 125</td>
<td>Introduction to Applied Statistics</td>
</tr>
<tr>
<td>PSYCH 251</td>
<td>Experimental Methods</td>
</tr>
<tr>
<td>PSYCH 252</td>
<td>Statistical Methods for Behavioral and Social Sciences</td>
</tr>
<tr>
<td>PSYCH 253</td>
<td>High-Dimensional Methods for Behavioral and Neural Data</td>
</tr>
<tr>
<td>STATS 203</td>
<td>Introduction to Regression Models and Analysis of Variance</td>
</tr>
<tr>
<td>EDUC 191</td>
<td>Introduction to Survey Research</td>
</tr>
<tr>
<td>HUMBIO 82A</td>
<td>Qualitative Research Methodology</td>
</tr>
<tr>
<td>ME Design</td>
<td></td>
</tr>
<tr>
<td>ME 101</td>
<td>Visual Thinking</td>
</tr>
<tr>
<td>ME 115A</td>
<td>Introduction to Human Values in Design</td>
</tr>
<tr>
<td>ME 203</td>
<td>Design and Manufacturing</td>
</tr>
<tr>
<td>ME 210</td>
<td>Introduction to Mechatronics</td>
</tr>
<tr>
<td>ME 216A</td>
<td>Advanced Product Design: Needfinding</td>
</tr>
<tr>
<td>EDUC 236</td>
<td>Beyond Bits and Atoms: Designing Technological Tools</td>
</tr>
<tr>
<td>EDUC 281</td>
<td>Technology for Learners</td>
</tr>
<tr>
<td>EDUC 239</td>
<td>Educating Young STEM Thinkers</td>
</tr>
<tr>
<td>EDUC 338</td>
<td>Innovations in Education</td>
</tr>
<tr>
<td>EDUC 342</td>
<td>Child Development and New Technologies</td>
</tr>
<tr>
<td>MS&amp;E 185</td>
<td>Global Work</td>
</tr>
<tr>
<td>MS&amp;E 231</td>
<td>Introduction to Computational Social Science</td>
</tr>
<tr>
<td>MS&amp;E 330</td>
<td>Law, Bias, &amp; Algorithms</td>
</tr>
<tr>
<td>Computer Music-</td>
<td></td>
</tr>
<tr>
<td>MUSIC 220A</td>
<td>Fundamentals of Computer-Generated Sound</td>
</tr>
<tr>
<td>MUSIC 220B</td>
<td>Compositional Algorithms, Psychoacoustics, and Computational Music</td>
</tr>
<tr>
<td>MUSIC 220C</td>
<td>Research Seminar in Computer-Generated Music</td>
</tr>
<tr>
<td>MUSIC 250A</td>
<td>Physical Interaction Design for Music</td>
</tr>
<tr>
<td>MUSIC 256A</td>
<td>Music, Computing, Design I: The Art of Design</td>
</tr>
<tr>
<td>Optional Elective</td>
<td>4</td>
</tr>
</tbody>
</table>

### Information Track—

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 124</td>
<td>From Languages to Information</td>
</tr>
<tr>
<td>CS 145</td>
<td>Data Management and Data Systems</td>
</tr>
<tr>
<td>Two courses, from different areas:</td>
<td>4</td>
</tr>
<tr>
<td>1) Information-based AI applications</td>
<td></td>
</tr>
<tr>
<td>CS 224N</td>
<td>Natural Language Processing with Deep Learning</td>
</tr>
<tr>
<td>CS 224S</td>
<td>Spoken Language Processing</td>
</tr>
<tr>
<td>CS 229</td>
<td>Machine Learning</td>
</tr>
<tr>
<td>CS 233</td>
<td>Geometric and Topological Data Analysis</td>
</tr>
<tr>
<td>CS 234</td>
<td>Reinforcement Learning</td>
</tr>
<tr>
<td>2) Database and Information Systems</td>
<td></td>
</tr>
<tr>
<td>CS 140</td>
<td>Operating Systems and Systems Programming</td>
</tr>
<tr>
<td>or CS 140E</td>
<td>Operating systems design and implementation</td>
</tr>
<tr>
<td>CS 245</td>
<td>Principles of Data-Intensive Systems</td>
</tr>
<tr>
<td>CS 246</td>
<td>Mining Massive Data Sets</td>
</tr>
<tr>
<td>CS 315</td>
<td>Project in Mining Massive Data Sets</td>
</tr>
<tr>
<td>CS 345</td>
<td>(Offered occasionally)</td>
</tr>
<tr>
<td>3) Information Systems in Biology</td>
<td></td>
</tr>
<tr>
<td>CS 235</td>
<td>Computational Methods for Biomedical Image Analysis and Interpretation</td>
</tr>
<tr>
<td>CS 270</td>
<td>Modeling Biomedical Systems: Ontology, Terminology, Problem Solving</td>
</tr>
<tr>
<td>CS 274</td>
<td>Representations and Algorithms for Computational Molecular Biology</td>
</tr>
<tr>
<td>4) Information Systems on the Web</td>
<td></td>
</tr>
<tr>
<td>CS 224W</td>
<td>Machine Learning with Graphs</td>
</tr>
<tr>
<td>CS 276</td>
<td>Information Retrieval and Web Search</td>
</tr>
<tr>
<td>At least three additional courses from the above areas or the general CS electives list. Students can replace one of these electives with a course found at <a href="https://cs.stanford.edu/explore">https://cs.stanford.edu/explore</a></td>
<td>4</td>
</tr>
</tbody>
</table>

### Systems Track—

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 140</td>
<td>Operating Systems and Systems Programming</td>
</tr>
<tr>
<td>or CS 140E</td>
<td>Operating systems design and implementation</td>
</tr>
<tr>
<td>Select one of the following:</td>
<td>3-4</td>
</tr>
<tr>
<td>CS 143</td>
<td>Compilers</td>
</tr>
<tr>
<td>EE 180</td>
<td>Digital Systems Architecture</td>
</tr>
<tr>
<td>Two additional courses from the list above or the following:</td>
<td>6-8</td>
</tr>
<tr>
<td>CS 144</td>
<td>Introduction to Computer Networking</td>
</tr>
<tr>
<td>CS 145</td>
<td>Data Management and Data Systems</td>
</tr>
<tr>
<td>CS 149</td>
<td>Parallel Computing</td>
</tr>
<tr>
<td>CS 155</td>
<td>Computer and Network Security</td>
</tr>
<tr>
<td>CS 190</td>
<td>Software Design Studio</td>
</tr>
<tr>
<td>CS 217</td>
<td>Hardware Accelerators for Machine Learning</td>
</tr>
<tr>
<td>CS 240</td>
<td>Advanced Topics in Operating Systems</td>
</tr>
<tr>
<td>CS 242</td>
<td>Programming Languages</td>
</tr>
<tr>
<td>CS 243</td>
<td>Program Analysis and Optimizations</td>
</tr>
<tr>
<td>CS 244</td>
<td>Advanced Topics in Networking</td>
</tr>
<tr>
<td>CS 245</td>
<td>Principles of Data-Intensive Systems</td>
</tr>
<tr>
<td>EE 271</td>
<td>Introduction to VLSI Systems</td>
</tr>
<tr>
<td>EE 282</td>
<td>Computer Systems Architecture</td>
</tr>
<tr>
<td>Track Electives: at least three additional courses selected from the list above, the general CS electives list, or the courses listed below. Students can replace one of these electives with a course found at: <a href="https://cs.stanford.edu/explore">https://cs.stanford.edu/explore</a></td>
<td>9-12</td>
</tr>
<tr>
<td>CS 241</td>
<td>Embedded Systems Workshop</td>
</tr>
<tr>
<td>CS 269Q</td>
<td>Elements of Quantum Computer Programming</td>
</tr>
<tr>
<td>CS 316</td>
<td>Advanced Multi-Core Systems</td>
</tr>
<tr>
<td>CS 341</td>
<td>Project in Mining Massive Data Sets</td>
</tr>
<tr>
<td>CS 344</td>
<td>Topics in Computer Networks (3 or more units, any suffix)</td>
</tr>
<tr>
<td>CS 345</td>
<td>(Advanced Topics in Database Systems - 3 or more units, any suffix. Offered occasionally.)</td>
</tr>
<tr>
<td>CS 349</td>
<td>Topics in Programming Systems (with permission of undergraduate advisor)</td>
</tr>
<tr>
<td>CS 448</td>
<td>Topics in Computer Graphics</td>
</tr>
</tbody>
</table>
Track Electives: at least three additional courses from the lists above, the general CS electives list, or the courses listed below. Students can replace one of these electives with a course found at: https://cs.stanford.edu/explore.

- CS 254B: Computational Complexity II
- CS 269G: Almost Linear Time Graph Algorithms
- CME 302: Numerical Linear Algebra
- CME 305: Discrete Mathematics and Algorithms
- PHIL 152: Computability and Logic

Unspecialized Track—

- CS 254: Introduction to Automata and Complexity Theory

Select one of the following: 4

- CS 140: Operating Systems and Systems Programming
- or CS 140E: Operating systems design and implementation
- CS 143: Compilers

One additional course from the list above or the following: 3-4

- CS 144: Introduction to Computer Networking
- CS 155: Computer and Network Security
- CS 190: Software Design Studio
- CS 242: Programming Languages
- CS 244: Advanced Topics in Networking
- EE 180: Digital Systems Architecture

Select one of the following: 3-4

- CS 221: Artificial Intelligence: Principles and Techniques
- CS 223A: Introduction to Robotics
- CS 228: Probabilistic Graphical Models: Principles and Techniques
- CS 229: Machine Learning
- CS 231A: Computer Vision: From 3D Reconstruction to Recognition

Select one of the following: 3-4

- CS 145: Data Management and Data Systems
- CS 147: Introduction to Human-Computer Interaction Design
- CS 148: Introduction to Computer Graphics and Imaging
- CS 235: Computational Methods for Biomedical Image Analysis and Interpretation
- CS 248: Interactive Computer Graphics

At least two courses from the general CS electives list 4

Individually Designed Track—

Students may propose an individually designed track. Proposals should include a minimum of 25 units and seven courses, at least four of which must be CS courses numbered 100 or above. See Handbook for Undergraduate Engineering Programs for further information.

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

Footnotes

1. MATH 19, MATH 20, and MATH 21, or MATH 41 and MATH 42, or AP Calculus Credit may be used as long as at least 26 MATH units are taken. AP Calculus Credit must be approved by the School of Engineering.
The math electives list consists of: MATH 51, MATH 52, MATH 53, MATH 104, MATH 107, MATH 108, MATH 109, MATH 110, MATH 113; CS 137, CS 205L, PHIL 151; CME 100, CME 102, CME 103 (or EE 103), CME 104. Restrictions: CS 157 and PHIL 151 may not be used in combination to satisfy the math electives requirement. Students who have taken both MATH 51 and MATH 52 may not count CME 100 as an elective. Courses counted as math electives cannot also count as CS electives, and vice versa.

The science elective may be any course of 3 or more units from the School of Engineering Science list (Fig. 4.2 in the UGHB), PSYCH 30, or AP Chemistry Credit. Either of the PHYSICS sequences 61/63 or 21/23 may be substituted for 41/43 as long as at least 11 science units are taken. AP Chemistry Credit and AP Physics Credit must be approved by the School of Engineering.


CS 205L is strongly recommended in this list for the Graphics track. Students taking CME 104 Linear Algebra and Partial Differential Equations for Engineers are also required to take its prerequisite, CME 102 Ordinary Differential Equations for Engineers.

Independent study projects (CS 191 Senior Project or CS 191W Writing Intensive Senior Project) require faculty sponsorship and must be approved by the adviser, faculty sponsor, and the CS senior project adviser (Patrick Young). A signed approval form, along with a brief description of the proposed project, should be filed the quarter before work on the project is begun. Further details can be found in the Handbook for Undergraduate Engineering Programs (UGHB) (http://ughb.stanford.edu).

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.

Honors Program in Computer Science

The Department of Computer Science (CS) offers an honors program for undergraduates whose academic records and personal initiative indicate that they have the necessary skills to undertake high-quality research in computer science. Admission to the program is by application only. To apply for the honors program, students must be majoring in Computer Science, have a grade point average (GPA) of at least 3.6 in courses that count toward the major, and achieve senior standing (135 or more units) by the end of the academic year in which they apply. C-terminal master's students are eligible to apply as long as they have not already received their undergraduate degree. Beyond these requirements, students who apply for the honors program must find a Computer Science faculty member who agrees to serve as the thesis adviser for the project. Thesis advisers must be members of Stanford’s Academic Council.

Students who meet the eligibility requirements and wish to be considered for the honors program must submit a written application to the CS undergraduate program office by May 1 of the year preceding the honors work. The application must include a letter describing the research project, a letter of endorsement from the faculty sponsor, and a transcript of courses taken at Stanford. Each year, a faculty review committee selects the successful candidates for honors from the pool of qualified applicants.

In order to receive departmental honors, students admitted to the honors program must, in addition to satisfying the standard requirements for the undergraduate degree, do the following:

1. Complete at least 9 units of CS 191 or CS 191W under the direction of their project sponsor.
2. Attend a weekly honors seminar Winter and Spring quarters.
3. Complete an honors thesis deemed acceptable by the thesis adviser and at least one additional faculty member.
4. Present the thesis at a public colloquium sponsored by the department.
5. Maintain the 3.6 GPA required for admission to the honors program.

Computer Science (CS) Minor

The following core courses fulfill the minor requirements. Prerequisites include the standard mathematics sequence through MATH 51 (or CME 100).

<table>
<thead>
<tr>
<th>Units</th>
<th>clt 106b or clt 106x</th>
<th>Programming Abstractions</th>
<th>Programming Abstractions</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>cs 103</th>
<th>Mathematical Foundations of Computing</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>cs 107</th>
<th>Computer Organization and Systems</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Units</th>
<th>cs 109</th>
<th>Introduction to Probability for Computer Scientists</th>
</tr>
</thead>
</table>

Electives (choose two courses from different areas):

- Artificial Intelligence—
  - CS 124 From Languages to Information
  - CS 221 Artificial Intelligence: Principles and Techniques
  - CS 229 Machine Learning

- Human-Computer Interaction—
  - CS 147 Introduction to Human-Computer Interaction Design

- Software—
  - CS 108 Object-Oriented Systems Design
  - CS 110 Principles of Computer Systems

- Systems—
  - CS 140 Operating Systems and Systems Programming
  - CS 140E Operating systems design and implementation
  - CS 143 Compilers
  - CS 144 Introduction to Computer Networking
  - CS 145 Data Management and Data Systems
  - CS 148 Introduction to Computer Graphics and Imaging

- Theory—
  - CS 154 Introduction to Automata and Complexity Theory
  - CS 157 Computational Logic
  - CS 161 Design and Analysis of Algorithms

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Note: for students with no programming background and who begin with CS 106A, the minor consists of seven courses.