Bioengineering

Bachelor of Science (BS)

Rated one of the top 10 Bioengineering undergraduate programs in the country, Bioengineering at Berkeley is a multidisciplinary major intended for academically strong students who excel in the physical sciences, mathematics, and biology. Coursework provides a strong foundation in engineering and the biological sciences, with the freedom to explore a variety of topics and specialize in advanced areas of research. All students benefit from intensive group design work, either through a senior capstone project (http://bioeng.berkeley.edu/undergrad/capstone) or through independent research in faculty laboratories. The major features small, specialized upper division courses, and direct interaction with faculty.

The stimulating environment of Berkeley offers a wealth of opportunity for learning, research, service, community involvement, and provides dedicated students the knowledge and skills to become the next leaders in bioengineering.

Course of Study Overview

The department offers one Bioengineering major, with several concentrations. For detailed descriptions of these concentrations, please see the department's website (http://bioeng.berkeley.edu/undergrad/program/concentrations).

- Biomedical Devices (http://bioeng.berkeley.edu/undergrad/program/devices)
- Biomedical Imaging (http://bioeng.berkeley.edu/undergrad/program/imaging)
- Cell & Tissue Engineering (http://bioeng.berkeley.edu/undergrad/program/celltissue)
- Synthetic & Computational Biology (http://bioeng.berkeley.edu/undergrad/program/syncompbio)

Admission to the Major

Prospective undergraduates of the College of Engineering will apply for admission to a specific program in the college. For further information, please see the College of Engineering's website (http://coe.berkeley.edu/students/prospective-students/admissions.html).

Admission to engineering via a Change of College application for current UC Berkeley students is not guaranteed. For further information regarding a Change of College to Engineering, please see the college's website (http://coe.berkeley.edu/student-services/degree-requirements/admission-to-a-specific-program-in-the-college).

Minor Program

The department offers a minor in Bioengineering that is open to all students who are not majoring in bioengineering and who have completed the necessary prerequisites for the minor. For further information regarding the prerequisites, please see the Minor Requirements tab on this page.

Joint Major

The Department of Bioengineering also offers a joint major with the Department of Materials Science and Engineering, for students who have an interest in the field of biomaterials. For further information regarding this program, please see the Bioengineering/Materials Science and Engineering joint major (http://guide.berkeley.edu/undergraduate/degree-programs/bioengineering-materials-science-engineering-joint-major) page in this Guide.

In addition to the University, campus, and college requirements, students must fulfill the below requirements specific to their major program.

General Guidelines

1. All technical courses taken in satisfaction of major requirements must be taken for a letter grade.
2. No more than one upper division course may be used to simultaneously fulfill requirements for a student's major and minor programs.
3. A minimum overall grade point average (GPA) of 2.0 is required for all work undertaken at UC Berkeley.
4. A minimum GPA of 2.0 is required for all technical courses taken in satisfaction of major requirements.

For information regarding residence requirements and unit requirements, please see the College Requirements tab.

For a detailed plan of study by year and semester, please see the Plan of Study tab.

Students are advised to consult the approved concentrations (http://bioeng.berkeley.edu/undergrad/program/concentrations) to identify an appropriate course sequence for bioengineering specialty areas, and may also design their own program that meets with the below requirements with permission from their faculty adviser. Regular consultation with an adviser is strongly encouraged. Recommended courses for each concentration can be found on the department's website (http://bioeng.berkeley.edu/undergrad/program/concentrations).

Summary of Major Requirements

The requirements for the Bioengineering Bachelor's Degree is a minimum of 120 semester units and must include the following:

1. A minimum of 24 total (http://bioeng.berkeley.edu/undergrad/program/#one) upper-division Bioengineering course units (including at least two bioengineering fundamentals (http://bioeng.berkeley.edu/undergrad/program/biofundamentals) courses, a bioengineering design (http://bioeng.berkeley.edu/undergrad/program/design) course, and a bioengineering laboratory (http://bioeng.berkeley.edu/undergrad/program/bioelabs) course)
2. A minimum of 36 total (http://bioeng.berkeley.edu/undergrad/program/#two) upper-division units in technical topics (http://bioeng.berkeley.edu/undergrad/program/techelect) courses
3. A minimum of 48 total units in engineering courses
4. Six courses (of at least 3 units each) selected to meet the college’s current humanities and social sciences requirements (http://engineering.berkeley.edu/student-services/degree-requirements/humanities-and-social-sciences)
5. One course with a substantial ethics component (http://bioeng.berkeley.edu/undergrad/program/ethics)
6. BioE 10 (http://bioeng.berkeley.edu/undergrad/program/#two), 11, 25, and 26
7. Math 1A, 1B, 53, and 54
8. Physics 7A and 7B
9. Chem 1A & 1AL (or 4A), and 3A & 3AL (or 12A)
10. E7 or CS 61A

**Lower Division Requirements**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BIO ENG 10</td>
<td>Introduction to Biomedicine for Engineers (Junior transfers exempt from requirement)</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 11</td>
<td>Engineering Molecules 1</td>
<td>3</td>
</tr>
<tr>
<td>BIO ENG 25</td>
<td>Careers in Biotechnology</td>
<td>1</td>
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<tr>
<td>BIO ENG 26</td>
<td>Introduction to Bioengineering</td>
<td>1</td>
</tr>
<tr>
<td>MATH 1A</td>
<td>Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 1B</td>
<td>Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 53</td>
<td>Multivariable Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 54</td>
<td>Linear Algebra and Differential Equations</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 7A</td>
<td>Physics for Scientists and Engineers</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 7B</td>
<td>Physics for Scientists and Engineers</td>
<td>4</td>
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<tr>
<td>CHEM 1A</td>
<td>General Chemistry &amp; General Chemistry Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>or CHEM 4A</td>
<td>General Chemistry and Quantitative Analysis</td>
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<tr>
<td>CHEM 3A</td>
<td>Chemical Structure and Reactivity &amp; Organic Chemistry Laboratory</td>
<td>5</td>
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<tr>
<td>or CHEM 12A</td>
<td>Organic Chemistry</td>
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<tr>
<td>ENGIN 7</td>
<td>Introduction to Computer Programming for Scientists and Engineers</td>
<td>4</td>
</tr>
<tr>
<td>or COMPSCI 61A</td>
<td>The Structure and Interpretation of Computer Programs</td>
<td></td>
</tr>
</tbody>
</table>

1 Not including BIO ENG 100, BIO ENG 198, BIO ENG 199, any other seminar-style courses or group meetings, or any course taken on a P/NP basis. Up to 4 units of letter-graded research (e.g., BIO ENG 196) can be included in the 24 units of upper-division Bioengineering courses. Up to 8 units of letter-graded research can be included in the 36 units of technical topics.

2 Not including any course taken on a P/NP basis; courses numbered 24, 39, 84; BIO ENG 100; COMPSCI 70; COMPSCI C79, COMPSCI 195, COMPSCI H195; DES INV courses (except DES INV 15, DES INV 22, DES INV 90E, DES INV 190E); ENGIN 125, ENGIN 157AC, ENGIN 180; IND ENG 95, IND ENG 172, IND ENG 185, IND ENG 186, IND ENG 190 series, IND ENG 191, IND ENG 192, IND ENG 195; MEC ENG 191K. There is no limit to the number of letter-graded research units that can be applied to the 48 engineering units. ENGIN 185 and ENGIN 187 cannot be used to fulfill engineering units.

3 Juniors transfers are exempted from taking BioE 10.

**Upper Division Requirements**

A total of 24 upper division Bioengineering units, including the following: 1

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BIO ENG 101</td>
<td>Instrumentation in Biology and Medicine</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 102</td>
<td>Biomechanics: Analysis and Design</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 103</td>
<td>Engineering Molecules 2 (Students will receive no credit for Bioengineering 103 after completing Chemistry 120B, Molecular Cell Biology C100A/Chemistry C130, or Physics 137)</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 104</td>
<td>Biological Transport Phenomena</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 110</td>
<td>Biomedical Physiology for Engineers</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 131</td>
<td>Introduction to Computational Molecular and Cell Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 144L</td>
<td>Protein Informatics Laboratory</td>
<td>3</td>
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</table>

**Bioengineering Fundamentals**

Choose two courses from the following:

<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BIO ENG 101</td>
<td>Instrumentation in Biology and Medicine</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 115</td>
<td>Tissue Engineering Lab</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 121L</td>
<td>BioMems and BioNanotechnology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 131</td>
<td>Introduction to Computational Molecular and Cell Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 136L</td>
<td>Laboratory in the Mechanics of Organisms</td>
<td>3</td>
</tr>
<tr>
<td>BIO ENG 140L</td>
<td>Synthetic Biology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 144L</td>
<td>Protein Informatics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>BIO ENG 163L</td>
<td>Molecular and Cellular Biophotonics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 168L</td>
<td>Practical Light Microscopy</td>
<td>3</td>
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</table>

**Bioengineering Lab**

Choose one course from the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>BIO ENG 101</td>
<td>Instrumentation in Biology and Medicine</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 115</td>
<td>Tissue Engineering Lab</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 121L</td>
<td>BioMems and BioNanotechnology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 131</td>
<td>Introduction to Computational Molecular and Cell Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 136L</td>
<td>Laboratory in the Mechanics of Organisms</td>
<td>3</td>
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<tr>
<td>BIO ENG 140L</td>
<td>Synthetic Biology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 144L</td>
<td>Protein Informatics Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>BIO ENG 163L</td>
<td>Molecular and Cellular Biophotonics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 168L</td>
<td>Practical Light Microscopy</td>
<td>3</td>
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</table>

**Technical Topics**

Choose 36 upper division units from the following:

<table>
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<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td>CHEM 120A</td>
<td>Physical Chemistry</td>
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<tr>
<td>CHEM 120B</td>
<td>Physical Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 135</td>
<td>Chemical Biology</td>
<td>3</td>
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<tr>
<td>CHM ENG 140</td>
<td>Introduction to Chemical Process Analysis</td>
<td>4</td>
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<tr>
<td>CHM ENG 141</td>
<td>Chemical Engineering Thermodynamics</td>
<td>4</td>
</tr>
<tr>
<td>CHM ENG 150A</td>
<td>Transport Processes</td>
<td>4</td>
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<tr>
<td>CHM ENG 150B</td>
<td>Transport and Separation Processes</td>
<td>4</td>
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<tr>
<td>CHM ENG 170A</td>
<td>Biochemical Engineering</td>
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<tr>
<td>CHM ENG 170B</td>
<td>Biochemical Engineering</td>
<td>3</td>
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<tr>
<td>CHM ENG 170C</td>
<td>Biochemical Engineering Laboratory</td>
<td>3</td>
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<tr>
<td>CHM ENG 171</td>
<td>Transport Phenomena</td>
<td>3</td>
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<tr>
<td>CHM ENG 178</td>
<td>Polymer Science and Technology</td>
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</tr>
<tr>
<td>COMPSCI 160</td>
<td>User Interface Design and Development</td>
<td>4</td>
</tr>
<tr>
<td>COMPSCI 161</td>
<td>Computer Security</td>
<td>4</td>
</tr>
<tr>
<td>COMPSCI 169</td>
<td>Software Engineering</td>
<td>4</td>
</tr>
<tr>
<td>COMPSCI 170</td>
<td>Efficient Algorithms and Intractable Problems</td>
<td>4</td>
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<tr>
<td>COMPSCI 176</td>
<td>Algorithms for Computational Biology</td>
<td>4</td>
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<tr>
<td>COMPSCI 186</td>
<td>Introduction to Database Systems</td>
<td>4</td>
</tr>
<tr>
<td>COMPSCI 188</td>
<td>Introduction to Artificial Intelligence</td>
<td>4</td>
</tr>
<tr>
<td>COMPSCI 189</td>
<td>Introduction to Machine Learning</td>
<td>4</td>
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<tr>
<td>COMPSCI C191</td>
<td>Quantum Information Science and Technology</td>
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<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Units</td>
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<tr>
<td>MCELLBI 148</td>
<td>Microbial Genomics and Genetics</td>
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<tr>
<td>MCELLBI 150</td>
<td>Molecular Immunology</td>
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<tr>
<td>MCELLBI 160L</td>
<td>Neurobiology Laboratory</td>
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<tr>
<td>MCELLBI 166</td>
<td>Biophysical Neurobiology</td>
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<tr>
<td>MEC ENG 102B</td>
<td>Mechatronics Design</td>
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<tr>
<td>MEC ENG 104</td>
<td>Engineering Mechanics II</td>
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<tr>
<td>MEC ENG 106</td>
<td>Fluid Mechanics</td>
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<tr>
<td>MEC ENG 109</td>
<td>Heat Transfer</td>
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<tr>
<td>MEC ENG 118</td>
<td>Introduction to Nanotechnology and Nanoscience</td>
<td></td>
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<tr>
<td>MEC ENG 119</td>
<td>Introduction to MEMS (Microelectromechanical Systems)</td>
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<tr>
<td>MEC ENG 132</td>
<td>Dynamic Systems and Feedback</td>
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<tr>
<td>MEC ENG 133</td>
<td>Mechanical Vibrations</td>
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<tr>
<td>MEC ENG 167</td>
<td>Microscale Fluid Mechanics</td>
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<tr>
<td>MEC ENG 185</td>
<td>Introduction to Continuum Mechanics</td>
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<tr>
<td>MAT SCI 102</td>
<td>Bonding, Crystallography, and Crystal Defects</td>
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<td>MAT SCI 103</td>
<td>Phase Transformations and Kinetics</td>
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<tr>
<td>MAT SCI 104</td>
<td>Materials Characterization</td>
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<tr>
<td>MAT SCI 111</td>
<td>Properties of Electronic Materials</td>
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<tr>
<td>MAT SCI 112</td>
<td>Corrosion (Chemical Properties)</td>
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<tr>
<td>MAT SCI 113</td>
<td>Mechanical Behavior of Engineering Materials</td>
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<tr>
<td>MAT SCI 130</td>
<td>Experimental Materials Science and Design</td>
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<tr>
<td>MAT SCI 151</td>
<td>Polymeric Materials</td>
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<tr>
<td>NUC ENG 101</td>
<td>Nuclear Reactions and Radiation</td>
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<tr>
<td>NUC ENG 107</td>
<td>Introduction to Imaging</td>
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<tr>
<td>NUC ENG 162</td>
<td>Radiation Biophysics and Dosimetry</td>
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<tr>
<td>PHYSICS 110A</td>
<td>Electromagnetism and Optics</td>
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<tr>
<td>PHYSICS 112</td>
<td>Introduction to Statistical and Thermal Physics</td>
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<tr>
<td>PHYSICS 137A</td>
<td>Quantum Mechanics</td>
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<tr>
<td>PHYSICS 177</td>
<td>Principles of Molecular Biophysics</td>
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<tr>
<td>PLANTBI C148</td>
<td>Microbial Genomics and Genetics</td>
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<tr>
<td>ENGIN 40</td>
<td>Engineering Thermodynamics</td>
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<tr>
<td>EL ENG 105</td>
<td>Microelectronic Devices and Circuits</td>
<td>4</td>
</tr>
<tr>
<td>EL ENG 117</td>
<td>Electromagnetic Fields and Waves</td>
<td>4</td>
</tr>
<tr>
<td>EL ENG 118</td>
<td>Introduction to Optical Engineering</td>
<td>3</td>
</tr>
<tr>
<td>EL ENG 120</td>
<td>Signals and Systems</td>
<td>4</td>
</tr>
<tr>
<td>EL ENG 123</td>
<td>Digital Signal Processing</td>
<td>4</td>
</tr>
<tr>
<td>EL ENG 126</td>
<td>Probability and Random Processes</td>
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<td>EECS 127</td>
<td>Optimization Models in Engineering</td>
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<td>EL ENG C128</td>
<td>Feedback Control Systems</td>
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<td>EL ENG 142</td>
<td>Integrated Circuits for Communications</td>
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<tr>
<td>EL ENG 143</td>
<td>Microfabrication Technology</td>
<td>4</td>
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<tr>
<td>EL ENG 147</td>
<td>Introduction to Microelectromechanical Systems (MEMS)</td>
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<tr>
<td>EL ENG 192</td>
<td>Mechatronic Design Laboratory</td>
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<tr>
<td>EECS 149</td>
<td>Introduction to Embedded Systems</td>
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<tr>
<td>INTEGBI 115</td>
<td>Introduction to Systems in Biology and Medicine</td>
<td>4</td>
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<tr>
<td>INTEGBI 127L</td>
<td>Motor Control with Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>INTEGBI 131</td>
<td>General Human Anatomy</td>
<td>3</td>
</tr>
<tr>
<td>INTEGBI 132</td>
<td>Survey of Human Physiology</td>
<td>4</td>
</tr>
<tr>
<td>INTEGBI 135</td>
<td>The Mechanics of Organisms</td>
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<tr>
<td>INTEGBI 148</td>
<td>Comparative Animal Physiology</td>
<td>3</td>
</tr>
<tr>
<td>INTEGBI 161</td>
<td>Population and Evolutionary Genetics</td>
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<td>INTEGBI 163</td>
<td>Molecular and Genomic Evolution</td>
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<td>INTEGBI 164</td>
<td>Human Genetics and Genomics</td>
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<tr>
<td>IND ENG 160</td>
<td>Nonlinear and Discrete Optimization</td>
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<td>IND ENG 162</td>
<td>Linear Programming and Network Flows</td>
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<td>IND ENG 172</td>
<td>Probability and Risk Analysis for Engineers</td>
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<td>Linear Algebra</td>
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<td>MATH 118</td>
<td>Fourier Analysis, Wavelets, and Signal Processing</td>
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<td>MATH 127</td>
<td>Mathematical and Computational Methods in Molecular Biology</td>
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<tr>
<td>MATH 128A</td>
<td>Numerical Analysis</td>
<td>4</td>
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<tr>
<td>MATH 170</td>
<td>Mathematical Methods for Optimization</td>
<td>4</td>
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<tr>
<td>MCEBLLI C100A</td>
<td>Biophysical Chemistry: Physical Principles and the</td>
<td>4</td>
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<tr>
<td></td>
<td>Molecules of Life (Students should take BioE 103 instead of</td>
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<td></td>
<td>MCB C100A, credit applied for those who have already taken</td>
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<td>C100A before F17)</td>
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<tr>
<td>MCEBLLI 100B</td>
<td>Biochemistry: Pathways, Mechanisms, and Regulation</td>
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<tr>
<td>MCEBLLI 102</td>
<td>Survey of the Principles of Biochemistry and</td>
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<td>Molecular Biology</td>
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<tr>
<td>MCEBLLI 110</td>
<td>Molecular Biology: Macromolecular Synthesis and</td>
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<td></td>
<td>Cellular Function</td>
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<tr>
<td>MCEBLLI C112</td>
<td>General Microbiology</td>
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</tr>
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<td>or PLANTBI C112</td>
<td>General Microbiology</td>
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<tr>
<td>MCEBLLI 130</td>
<td>Cell and Systems Biology</td>
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<tr>
<td>MCEBLLI 132</td>
<td>Biology of Human Cancer</td>
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<tr>
<td>MCEBLLI 133L</td>
<td>Physiology and Cell Biology Laboratory</td>
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<tr>
<td>MCEBLLI 136</td>
<td>Physiology</td>
<td>4</td>
</tr>
<tr>
<td>MCEBLLI 140</td>
<td>General Genetics</td>
<td>4</td>
</tr>
<tr>
<td>MCEBLLI 140L</td>
<td>Genetics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>MCEBLLI C148</td>
<td>Microbial Genomics and Genetics</td>
<td>4</td>
</tr>
</tbody>
</table>

1. Not including BIO ENG 100, BIO ENG 198, BIO ENG 199, any other seminar-style courses or group meetings, or any course taken on a P/NP basis. Up to 4 units of letter-graded research (e.g., BIO ENG 196) can be included in the 24 units of upper-division Bioengineering courses. Up to 8 units of letter-graded research can be included in the 36 units of technical topics.
2. Students should take BioE 103 instead of MCB C100A. Credit applied for those who have already taken C100A before F17.

**Bioengineering Design Project or Research**

Choose one course from the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIO ENG 101</td>
<td>Instrumentation in Biology and Medicine</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 121L</td>
<td>BioMems and BioNanotechnology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 140L</td>
<td>Synthetic Biology Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 145</td>
<td>Intro to Machine Learning in Computational Biology</td>
<td>4</td>
</tr>
<tr>
<td>BIO ENG 168L</td>
<td>Practical Light Microscopy</td>
<td>3</td>
</tr>
</tbody>
</table>

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**University of California, Berkeley**
**General Guidelines**

1. All courses taken to fulfill the minor requirements must be taken for graded credit.

2. A minimum technical grade point average of 3.0 (math, science & engineering courses) is required for acceptance into the minor program.

3. A minimum grade point average (GPA) of 2.0 is required for courses used to fulfill the minor requirements.

4. No more than one upper division course may be used to simultaneously fulfill requirements for a student’s major and minor programs.

5. Completion of the minor program cannot delay a student’s graduation.

6. Please see more details at the department website (http://bioeng.berkeley.edu/undergrad/bioeminor).

**Procedure**

- **Students should apply first, before taking courses.** Applications are available in 306 Stanley Hall or on the department website (http://bioeng.berkeley.edu/undergrad/bioeminor). Completed applications should be returned to 306 Stanley Hall. Please include an unofficial copy of your transcript with the application.

- The department will approve or deny the application. If approved, the department will contact the student via email advising of the decision.

- Upon completion of the requirements for the minor, the student should complete the Confirmation of Completion form (http://bioeng.berkeley.edu/undergrad/bioeminor). Please submit the form along with an unofficial transcript to 306 Stanley Hall.

- The department will verify the completion of the minor and send the original form to the Office of the Registrar. (Note: for graduating seniors, this must be done no later than two weeks after the end of the term.)

- A notation in the memorandum section of the student’s transcript will indicate completion of the minor.

**Recommended Preparation**

The upper division requirements for the BioE minor require competency in subject matters covered in the following recommended courses.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 3A</td>
<td>Chemical Structure and Reactivity</td>
<td>3</td>
</tr>
<tr>
<td>MATH 53</td>
<td>Multivariable Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 54</td>
<td>Linear Algebra and Differential Equations</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 7A</td>
<td>Physics for Scientists and Engineers</td>
<td>4</td>
</tr>
<tr>
<td>PHYSICS 7B</td>
<td>Physics for Scientists and Engineers</td>
<td>4</td>
</tr>
</tbody>
</table>

\* Students who have already taken PHYSICS 8A and PHYSICS 8B may substitute them for these courses.

**Upper Division Minor Requirements**

- One course from the BioE Fundamentals List (p. 1)
- Two upper division courses from the Technical Topics List (p. 1)
- Two upper division bioengineering courses.

**Students in the College of Engineering must complete no fewer than 120 semester units with the following provisions:**

1. Completion of the requirements of one engineering major program (http://engineering.berkeley.edu/academics/undergraduate-programs) study.

2. A minimum overall grade point average of 2.00 (C average) and a minimum 2.00 grade point average in upper division technical coursework required of the major.

3. The final 30 units and two semesters must be completed in residence in the College of Engineering on the Berkeley campus.

4. All technical courses (math, science and engineering) that can fulfill requirements for the student’s major must be taken on a letter graded basis (unless they are only offered P/NP).

5. Entering freshmen are allowed a maximum of eight semesters to complete their degree requirements. Entering junior transfers are allowed a maximum of four semesters to complete their degree requirements. (Note: junior transfers admitted missing three or more courses from the lower division curriculum are allowed five semesters.) Summer terms are optional and do not count toward the
maximum. Students are responsible for planning and satisfactorily completing all graduation requirements within the maximum allowable semesters.

6. Adhere to all college policies and procedures (http://engineering.berkeley.edu/academics/undergraduate-guide) as they complete degree requirements.

7. Complete the lower division program before enrolling in upper division engineering courses.

Humanities and Social Sciences (H/SS) Requirement
To promote a rich and varied educational experience outside of the technical requirements for each major, the College of Engineering has a six-course Humanities and Social Sciences breadth requirement (http://engineering.berkeley.edu/student-services/degree-requirements/humanities-and-social-sciences), which must be completed to graduate. This requirement, built into all the engineering programs of study, includes two reading and composition courses (R&C), and four additional courses within which a number of specific conditions must be satisfied. Follow these guidelines to fulfill this requirement:

1. Complete a minimum of six courses from the approved Humanities/Social Sciences (H/SS) lists (http://engineering.berkeley.edu/hssreq).

2. Courses must be a minimum of 3 semester units (or 4 quarter units).

3. Two of the six courses must fulfill the college’s Reading and Composition (R&C) requirement. These courses must be taken for a letter grade (C- or better required) and must be completed by no later than the end of the Sophomore year (fourth semester of enrollment). The first half of R&C, the “A” course, must be completed by the end of the freshman year; the second half of R&C, the “B” course, must be completed by no later than the end of the Sophomore year. Use the Class Schedule (http://classes.berkeley.edu) to view R&C courses offered in a given semester. View the list of exams (http://engineering.berkeley.edu/academics/undergraduate-guide/exams) that can be applied toward the first half of the R&C requirement. Note: Only the first half of R&C can be fulfilled with an AP or IB exam score. Test scores do not fulfill the second half of the R&C requirement for College of Engineering students.

4. The four additional courses must be chosen within College of Engineering guidelines from the H/SS lists (see below). These courses may be taken on a Pass/Not Passed basis (P/NP).

5. Two of the six courses must be upper division (courses numbered 100-196).

6. One of the six courses must satisfy the campus American Cultures requirement. For detailed lists of courses that fulfill American Cultures requirements, visit the American Cultures (http://guide.berkeley.edu/undergraduate/colleges-schools/engineering/american-cultures-requirement) site.

7. A maximum of two exams (Advanced Placement, International Baccalaureate, or A-Level) may be used toward completion of the H/SS requirement. View the list of exams (http://engineering.berkeley.edu/academics/undergraduate-guide/exams) that can be applied toward H/SS requirements.

8. Courses may fulfill multiple categories. For example, CY PLAN 118AC (http://guide.berkeley.edu/search/?P=CY%20PLAN%20118AC) satisfies both the American Cultures requirement and one upper division H/SS requirement.

9. No courses offered by any engineering department other than BIO ENG 100 (http://guide.berkeley.edu/search/?P=BIO %20ENG%20100), COMPSCI C79 (http://guide.berkeley.edu/search/?P=COMPSCI%20C79), ENGIN 125 (http://guide.berkeley.edu/search/?P=ENGIN%20125), ENGIN 157AC (http://guide.berkeley.edu/search/?P=ENGIN%20157AC), and MEC ENG 191K (http://guide.berkeley.edu/search/?P=MEC%20ENG%20191K) may be used to complete H/SS requirements.

10. Foreign language courses may be used to complete H/SS requirements. View the list of language options (http://guide.berkeley.edu/undergraduate/colleges-schools/engineering/ approved-foregn-language-courses).

11. Courses numbered 97, 98, 99, or above 196 may not be used to complete any H/SS requirement.

12. The College of Engineering uses modified versions of five of the College of Letters and Science (L&S) breadth requirements lists to provide options to our students for completing the H/SS requirement. The five areas are:

- Arts and Literature
- Historical Studies
- International Studies
- Philosophy and Values
- Social and Behavioral Sciences

Within the guidelines above, choose courses from any of the Breadth areas listed above. (Please note that you cannot use courses on the Biological Science or Physical Science Breadth list to complete the H/SS requirement.) To find course options, go to the Class Schedule (http://classes.berkeley.edu), (http://classes.berkeley.edu/search/class) select the term of interest, and use the Breadth Requirements (https://ls.berkeley.edu/sites/default/files/breadth_search_annotation_in_guide.png) filter.

Class Schedule Requirements

- Minimum units per semester: 12.0
- Maximum units per semester: 20.5
- Minimum technical courses: College of Engineering undergraduates must enroll each semester in no fewer than two technical courses (of a minimum of 3 units each) required of the major program of study in which the student is officially declared. (Note: For most majors, normal progress will require enrolling in 3-4 technical courses each semester).
- All technical courses (math, science, engineering) that satisfy requirements for the major must be taken on a letter-graded basis (unless only offered as P/NP).

Minimum Academic (Grade) Requirements

- A minimum overall and semester grade point average of 2.00 (C average) is required of engineering undergraduates. Students will be subject to dismissal from the University if during any fall or spring semester their overall UC GPA falls below a 2.00, or their semester GPA is less than 2.00.
- Students must achieve a minimum grade point average of 2.00 (C average) in upper division technical courses required for the major curriculum each semester.
- A minimum overall grade point average of 2.00, and a minimum 2.00 grade point average in upper division technical course work required for the major is needed to earn a Bachelor of Science in Engineering.
Unit Requirements

To earn a Bachelor of Science in Engineering, students must complete at least 120 semester units of courses subject to certain guidelines:

- Completion of the requirements of one engineering major program (https://engineering.berkeley.edu/academics/undergraduate-guide/degree-requirements-major-programs) of study.
- A maximum of 16 units of special studies coursework (courses numbered 97, 98, 99, 197, 198, or 199) is allowed towards the 120 units.
- A maximum of 4 units of physical education from any school attended will count towards the 120 units.
- Students may receive unit credit for courses graded P (including P/NP units taken through EAP) up to a limit of one-third of the total units taken and passed on the Berkeley campus at the time of graduation.

Normal Progress

Students in the College of Engineering must enroll in a full-time program and make normal progress each semester toward the bachelor’s degree. The continued enrollment of students who fail to achieve minimum academic progress shall be subject to the approval of the dean. (Note: Students with official accommodations established by the Disabled Students’ Program, with health or family issues, or with other reasons deemed appropriate by the dean may petition for an exception to normal progress rules.)

University of California Requirements

Entry Level Writing (http://guide.berkeley.edu/undergraduate/colleges-schools/natural-resources/entry-level-writing-requirement)

All students who will enter the University of California as freshmen must demonstrate their command of the English language by fulfilling the Entry Level Writing Requirement. Satisfaction of this requirement is also a prerequisite to enrollment in all reading and composition courses at UC Berkeley.

American History and American Institutions (http://guide.berkeley.edu/undergraduate/colleges-schools/natural-resources/american-history-institutions-requirement)

The American History and Institutions requirements are based on the principle that a U.S. resident graduated from an American university should have an understanding of the history and governmental institutions of the United States.

Campus Requirement

American Cultures (http://guide.berkeley.edu/undergraduate/colleges-schools/natural-resources/american-cultures-requirement)

American Cultures (AC) is the one requirement that all undergraduate students at UC Berkeley need to take and pass in order to graduate. The requirement offers an exciting intellectual environment centered on the study of race, ethnicity, and culture in the United States. AC courses offer students opportunities to be part of research-led, highly accomplished teaching environments, grappling with the complexity of American Culture.

For more detailed information regarding the courses listed below (e.g., elective information, GPA requirements, etc.), please see the College Requirements and Major Requirements tabs.

<table>
<thead>
<tr>
<th>Course</th>
<th>Fall</th>
<th>Units</th>
<th>Spring</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 1A</td>
<td></td>
<td>4 MATH 1B</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>BIO ENG 10</td>
<td></td>
<td>4 PHYSICS 7A</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(taken in Sophomore year in Synthetic Biology concentration)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM 1A &amp; 1AL</td>
<td></td>
<td>4 CHEM 3A &amp; 3AL</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>BIO ENG 26</td>
<td></td>
<td>1 BIO ENG 25</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Reading and Composition</td>
<td></td>
<td>4 Reading and Composition</td>
<td>4</td>
<td></td>
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<tr>
<td></td>
<td>17</td>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>MATH 53</td>
<td></td>
<td>4 BIO ENG 11</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>PHYSICS 7B</td>
<td></td>
<td>4 MATH 54</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>ENGIN 7 or COMPSCI 61A</td>
<td></td>
<td>4 Humanities/ Social Sciences course</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Humanities/Social Sciences course</td>
<td></td>
<td>3 Additional course per concentration</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>BIO ENG 100 (or Humanities/Social Sciences course with Ethics content)</td>
<td>3 Humanities/ Social Sciences course</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td>13</td>
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</tr>
<tr>
<td></td>
<td>15</td>
<td></td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

Total Units: 120

1 Junior transfer admits are exempt from completing BIO ENG 10.

Mission

Since our founding in 1998, the BioE faculty have been working to create an integrated, comprehensive program. Much thought has been put into the question, “What does every bioengineer need to know?” The faculty have been engaged in considerable dialogue over the years about what
needs to be included, in what order, and how to do so in a reasonable time frame. Balancing depth with breadth has been the key challenge, and we have reached a point where the pieces have come together to form a coherent bioengineering discipline.

**Learning Goals for the Major**

1. Describe the fundamental principles and methods of engineering.
2. Understand the physical, chemical, and mathematical basis of biology.
3. Appreciate the different scales of biological systems.
4. Apply the physical sciences and mathematics in an engineering approach to biological systems.
5. Effectively communicate scientific and engineering data and ideas, both orally and in writing.
6. Demonstrate the values of cooperation, teamwork, social responsibility, and lifelong learning necessary for success in the field.
7. Design a bioengineering solution to a problem of technical, scientific, or societal importance.
8. Demonstrate advanced knowledge in a specialized field of bioengineering.

Bioengineering provides an array of programmatic and individual advising services. Each student is strongly encouraged to consult with a faculty adviser each semester. Our dedicated Bioengineering undergraduate affairs officer is available through appointments or drop-in times to consult on topics such as course selection, degree requirements, concentration selection, and achieving personal and academic goals. Further advising support is available from staff in the Engineering Student Services Office.

Please see more information on advising on the department website (http://bioeng.berkeley.edu/undergrad/advising).

**Advising Staff and Hours**

**Undergraduate Adviser:**
Cindy Manly-Fields
Phone: 510-642-5860
cmanly@berkeley.edu
306C Stanley Hall

**Appointment times:** Monday – Friday, 9am- 11:30am
**Afternoon drop-in time:** Tuesday-Thursday, 1:15-5pm, Friday 2-4pm

**Undergraduate Research**

We believe it is essential for undergraduates to experience the hands-on application of skills to prepare them for a career in bioengineering. Every student is required to complete at least one semester of research or design before graduation, although most do more. This can be accomplished through our outstanding senior capstone design course (http://bioeng.berkeley.edu/undergrad/capstone), or through other independent study options and research in faculty laboratories. A recent survey shows that 94% of our senior students have undertaken extracurricular research, usually starting in their sophomore year. For research resources, please visit the department website (http://bioeng.berkeley.edu/undergrad/undergradresearch).

**Student Organizations**

There are several active student organizations related to bioengineering, focusing on academics, research, global healthcare, local outreach, social life, career planning, and other worthy efforts. For further information, please see the Student Life (http://bioeng.berkeley.edu/resources/student-life) page on the department website.

**Bioengineering**

Expand all course descriptions [+] Collapse all course descriptions [-]

**BIO ENG 10 Introduction to Biomedicine for Engineers 4 Units**

Terms offered: Fall 2018, Fall 2017, Fall 2016

This course is intended for lower division students interested in acquiring a foundation in biomedicine with topics ranging from evolutionary biology to human physiology. The emphasis is on the integration of engineering applications to biology and health. The specific lecture topics and exercises will include the key aspects of genomics and proteomics as well as topics on plant and animal evolution, stem cell biomedicine, and tissue regeneration and replacement. Medical physiology topics include relevant engineering aspects of human brain, heart, musculoskeletal, and other systems.

**Introduction to Biomedicine for Engineers: Read More [+]**

**Objectives Outcomes**

**Student Learning Outcomes:** The goal is for undergraduate engineering students to gain sufficient biology and human physiology fundamentals so that they are better prepared to study specialized topics, e.g., biomechanics, imaging, computational biology, tissue engineering, biomonitoring, drug development, robotics, and other topics covered by upper division and graduate courses in UC Berkeley departments of Molecular and Cell Biology, Integrative Biology, Bioengineering, Electrical Engineering and Computer Science, Mechanical Engineering, and courses in the UC San Francisco Division of Bioengineering.

**Rules & Requirements**

**Prerequisites:** Math 1A, Math 16A, or equivalent (can be taken concurrently)

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructors:** Conboy, Kumar, Johnson

Introduction to Biomedicine for Engineers: Read Less [-]
BIO ENG 11 Engineering Molecules 1 3 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
This course focuses on providing students with a foundation in organic chemistry and biochemistry needed to understand contemporary problems in synthetic biology, biomaterials and computational biology.
Engineering Molecules 1: Read More [+]

Objectives Outcomes

Course Objectives: The goal of this course is to give students the background in organic chemistry and biochemistry needed understand problems in synthetic biology, biomaterials and molecular imaging. Emphasis is on basic mechanisms

Student Learning Outcomes: Students will learn aspects of organic and biochemistry required to begin the rational manipulation and/or design of biological systems and the molecules they are comprised of.

Rules & Requirements

Prerequisites: Chemistry 3A

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Engineering Molecules 1: Read Less [-]

BIO ENG 24 Freshmen Seminar 1 Unit
Terms offered: Spring 2018, Spring 2017, Fall 2016
The Berkeley Seminar Program has been designed to provide new students with the opportunity to explore an intellectual topic with a faculty member in a small-seminar setting. Berkeley seminars are offered in all campus departments, and topics vary from department to department and semester to semester.
Freshmen Seminar: Read More [+]

Rules & Requirements

Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 1 hour of seminar per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam required.

Freshmen Seminar: Read Less [-]

BIO ENG 25 Careers in Biotechnology 1 Unit
Terms offered: Spring 2019, Spring 2018, Spring 2017
This introductory seminar is designed to give freshmen and sophomores an opportunity to explore specialties related to engineering in the pharmaceutical/biotech field. A series of one-hour seminars will be presented by industry professionals, professors, and researchers.
Topics may include biotechnology and pharmaceutical manufacturing; process and control engineering; drug inspection process; research and development; compliance and validation; construction process for a GMP facility; project management; and engineered solutions to environmental challenges. This course is of interest to students in all areas of engineering and biology, including industrial engineering and manufacturing, chemical engineering, and bioengineering.
Careers in Biotechnology: Read More [+]

Rules & Requirements

Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 1 hour of seminar per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam required.

Careers in Biotechnology: Read Less [-]
BIO ENG 26 Introduction to Bioengineering 1 Unit

Terms offered: Fall 2018, Fall 2017

This introductory seminar is designed to give freshmen and sophomores a glimpse of a broad selection of bioengineering research that is currently underway at Berkeley and UCSF. Students will become familiar with bioengineering applications in the various concentration areas and see how engineering principles can be applied to biological and medical problems.

Introduction to Bioengineering: Read More [+]

Objectives Outcomes

Course Objectives: This course is designed to expose students to current research and problems in bioengineering. As a freshman/sophomore class, its main purpose is to excite our students about the possibilities of bioengineering and to help them to choose an area of focus.

Student Learning Outcomes: This course demonstrates the rapid pace of new technology and the need for life-long learning (2). In addition, the course, because of its state-of-the-art research content, encourages our students to explore new horizons (3).

Hours & Format

Fall and/or spring: 15 weeks - 1 hour of seminar per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.

Instructors: T. Johnson, H. Lam

Introduction to Bioengineering: Read Less [-]

BIO ENG 84 Sophomore Seminar 1 or 2 Units

Terms offered: Spring 2019, Spring 2018, Spring 2017

Sophomore seminars are small interactive courses offered by faculty members in departments all across the campus. Sophomore seminars offer opportunity for close, regular intellectual contact between faculty members and students in the crucial second year. The topics vary from department to department and semester to semester. Enrollment limited to 15 sophomores.

Sophomore Seminar: Read More [+]

Rules & Requirements

Prerequisites: At discretion of instructor

Repeat rules: Course may be repeated for credit when topic changes.

Hours & Format

Fall and/or spring:
5 weeks - 3-6 hours of seminar per week
10 weeks - 1.5-3 hours of seminar per week
15 weeks - 1-2 hours of seminar per week

Summer:
6 weeks - 2.5-5 hours of seminar per week
8 weeks - 1.5-3.5 hours of seminar and 2-4 hours of seminar per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: The grading option will be decided by the instructor when the class is offered. Final exam required.

Sophomore Seminar: Read Less [-]

BIO ENG 98 Supervised Independent Group Studies 1 - 4 Units

Terms offered: Spring 2019, Fall 2018, Spring 2018

Organized group study on various topics under the sponsorship of a member of the Bioengineering faculty.

Supervised Independent Group Studies: Read More [+]

Rules & Requirements

Prerequisites: Consent of instructor

Credit Restrictions: Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog.

Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 1-4 hours of directed group study per week

Summer: 8 weeks - 1-4 hours of directed group study per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.

Supervised Independent Group Studies: Read Less [-]
BIO ENG 99 Supervised Independent Study and Research 1 - 4 Units
Terms offered: Fall 2018, Fall 2017, Spring 2017
Supervised independent study for lower division students.
Rules & Requirements
Prerequisites: Freshman or sophomore standing and consent of instructor
Credit Restrictions: Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog.
Repeat rules: Course may be repeated for credit without restriction.
Hours & Format
Fall and/or spring: 15 weeks - 1-4 hours of independent study per week
Summer: 8 weeks - 1.5-7.5 hours of independent study per week
10 weeks - 1.5-6 hours of independent study per week
Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.
Supervised Independent Study and Research: Read Less [-]

BIO ENG 100 Ethics in Science and Engineering 3 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
The goal of this semester course is to present the issues of professional conduct in the practice of engineering, research, publication, public and private disclosures, and in managing professional and financial conflicts. The method is through historical didactic presentations, case studies, presentations of methods for problem solving in ethical matters, and classroom debates on contemporary ethical issues. The faculty will be drawn from national experts and faculty from religious studies, journalism, and law from the UC Berkeley campus.
Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week
Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructors: Lam, Hayley
Ethics in Science and Engineering: Read Less [-]

BIO ENG 101 Instrumentation in Biology and Medicine 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
This course teaches the fundamental principles underlying modern sensing and control instrumentation used in biology and medicine. The course takes an integrative analytic and hands-on approach to measurement theory and practice by presenting and analyzing example instruments currently used for biology and medical research, including EEG, ECG, pulsed oximeters, Complete Blood Count (CBC), etc.
Objectives Outcomes
Course Objectives: Students should understand the architecture and design principles of modern biomedical sensor data-acquisition (sensor-DAQ) systems. They should understand how to choose the appropriate biomedical sensor, instrumentation amplifier, number of bits, sampling rate, anti-aliasing filter, and DAQ system. They will learn how to design a low-noise instrumentation amplifier circuit. They should understand the crucial importance of suppressing 60 Hz and other interferences to acquire high quality low-level biomedical signals. They should understand the design principles of building, debugging.
Student Learning Outcomes: Students will achieve knowledge and skills in biomedical signal acquisition. They will be assessed in their success with the Course Objectives through tests, homeworks, and laboratories. In particular, the tests will ensure that the students have absorbed the theoretical concepts. The laboratories will provide assessment of learning practical skills (e.g., building an ECG circuit).
Rules & Requirements
Prerequisites: El Eng 16A & 16B, Math 53, 54, Physics 7A-7B, or consent of instructor
Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 3 hours of laboratory per week
Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Conolly
Instrumentation in Biology and Medicine: Read Less [-]
**BIO ENG 102 Biomechanics: Analysis and Design 4 Units**

Terms offered: Fall 2018, Fall 2017, Fall 2016

This course introduces, develops and applies the methods of continuum mechanics to biomechanical phenomena abundant in biology and medicine. It is intended for upper level undergraduate students who have been exposed to vectors, differential equations, and undergraduate course(s) in physics and certain aspects of modern biology.

**Objectives**

**Course Objectives:** This course introduces, develops and applies scaling laws and the methods of continuum mechanics to biomechanical phenomena related to tissue or organ levels. It is intended for upper level undergraduate students who have been exposed to vectors, differential equations, and undergraduate course(s) in physics and certain aspects of modern biology.

Topics include:
- Biosolid mechanics
- Stress, strain, constitutive equation
- Vector and tensor math
- Equilibrium
- Extension, torsion, bending, buckling
- Material properties of tissues

**Student Learning Outcomes:** The course will equip the students with a deep understanding of principles of biomechanics. The intuitions gained in this course will help guide the analysis of design of biomedical devices and help the understanding of biological/medical phenomena in health and disease. The students will develop insight, skills and tools in quantitative analysis of diverse biomechanical systems and topics, spanning various scales from cellular to tissue and organ levels.

**Rules & Requirements**

**Prerequisites:** Math 53, 54; Physics 7A

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructor:** Mofrad

**Engineering Molecules 2: Read Less [-]**

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**BIO ENG 103 Engineering Molecules 2 4 Units**

Terms offered: Fall 2018, Fall 2017, Fall 2016

Thermodynamic and kinetic concepts applied to understanding the chemistry and structure of biomolecules (proteins, membranes, DNA, and RNA) and their thermodynamic and kinetic features in the crowded cellular environment. Topics include entropy, bioenergetics, free energy, chemical potential, reaction kinetics, enzyme kinetics, diffusion and transport, non-equilibrium systems, and their connections to the cellular environment.

**Objectives**

**Course Objectives:** (1) To introduce the basics of thermodynamics and chemical kinetics for molecular to cellular biological systems; (2) To give students an understanding of biological size and timescales illustrated through computational exercises on model problems in physical biology.

**Student Learning Outcomes:** students will be able to (1) relate statistical thermodynamics and chemical kinetics to analyze molecular and cellular behavior beyond the ideal gas and Carnot cycle.

**Rules & Requirements**

**Prerequisites:** Bio1ogy 1A or Bioengineering 11, Physics 7A-7B, Math 1A, 1B, 53, 54

**Credit Restrictions:** Students will receive no credit for Bioengineering 103 after completing Chemistry 120B, or Molecular Cell Biology C100A/Chemistry C130.

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructor:** Head-Gordon

**Engineering Molecules 2: Read Less [-]**
BIO ENG 104 Biological Transport Phenomena 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
The transport of mass, momentum, and energy are critical to the function of living systems and the design of medical devices. Biological transport phenomena are present at a wide range of length scales: molecular, cellular, organ (whole and by functional unit), and organism. This course develops and applies scaling laws and the methods of continuum mechanics to biological transport phenomena over a range of length and time scales. The course is intended for undergraduate students who have taken a course in differential equations and an introductory course in physics. Students should be familiar with basic biology; an understanding of physiology is useful, but not assumed.

Rules & Requirements

Prerequisites: Mathematics 53, 54, and Physics 7A

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 3 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Johnson

BIO ENG 105 Engineering Devices 1 4 Units
Terms offered: Fall 2018
This course provides students with an introduction to medical device design through fundamentals of circuit design/analysis, signal processing, and instrumentation development from concept to market. Important concepts will include impulse responses of systems, op-amps, interference, and noise; the origin of biological signals and recording mechanisms; and design considerations including sensitivity, accuracy, and market potential. This course is designed to be an introduction to these tools and concepts to prepare students to engage deeply and mindfully with device design in their future courses.

Rules & Requirements

Prerequisites: Math 53 and Physics 7A & 7B required

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Moriel Vandsburger
BIO ENG C106A Introduction to Robotics 4 Units
Terms offered: Fall 2018, Fall 2017
An introduction to the kinematics, dynamics, and control of robot manipulators, robotic vision, and sensing. The course covers forward and inverse kinematics of serial chain manipulators, the manipulator Jacobian, force relations, dynamics, and control. It presents elementary principles on proximity, tactile, and force sensing, vision sensors, camera calibration, stereo construction, and motion detection. The course concludes with current applications of robotics in active perception, medical robotics, and other areas.

Introduction to Robotics: Read More [+]

Rules & Requirements

Prerequisites: Electrical Engineering 120 or equivalent, consent of instructor

Credit Restrictions: Students will receive no credit for Electrical Engineering and Computer Science C106A/Bioengineering C106A after completing EE C106A/BioE C125, Electrical Engineering 206A, or Electrical Engineering and Computer Science 206A.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture, 1 hour of discussion, and 3 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Alternative to final exam.

Instructor: Bajcsy

Also listed as: EECS C106A

Introduction to Robotics: Read Less [-]
BIO ENG 110 Biomedical Physiology for Engineers 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
This course introduces students to the physiology of human organ systems, with an emphasis on quantitative problem solving, engineering-style modeling, and applications to clinical medicine. Biomedical Physiology for Engineers: Read More [+]

Objectives Outcomes
Course Objectives: This 15-week course will introduce students to the principles of medical physiology, with a strong emphasis on quantitative problem solving, the physiological basis of human disease, and applications to biomedical devices and prostheses.

Student Learning Outcomes: Students will be exposed to the basic physiological systems which govern the function of each organ system, examples of diseases in which these systems go awry, and medical devices which have been developed to correct the deficits.

Rules & Requirements
Prerequisites: BioE 10, BioE 11 or Biology 1A; Math 54 recommended

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Kumar

Biomedical Physiology for Engineers: Read Less [-]

BIO ENG 111 Functional Biomaterials Development and Characterization 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
This course is intended for upper level engineering undergraduate students interested in the development of novel functional proteins and peptide motifs and characterization of their physical and biological properties using various instrumentation tools in quantitative manners. The emphasis of the class is how to develop novel proteins and peptide motifs, and to characterize their physical and biological functions using various analytical tools in quantitative manners.

Functional Biomaterials Development and Characterization: Read More [+]

Objectives Outcomes
Course Objectives: To provide students with basic and extended concepts for the development of the functional proteins and their characterization for various bioengineering and biomedical purposes.

Student Learning Outcomes: Upon completing the course, the student should be able:
1. To understand the directed evolution processes of functional proteins.
2. To identify the natural protein products from proteomic database.
3. To design various experiments to characterize the new protein products.
4. To develop novel functional proteins and characterize their properties.
5. To understand basic concepts and instrumentation of protein characterization tools.

Rules & Requirements
Prerequisites: Chemistry 1A or 4A, Bio Eng 11 or Biology 1A; Bio Eng 103 or equivalent

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: SW Lee

Functional Biomaterials Development and Characterization: Read Less [-]
BIO ENG C112 Molecular Biomechanics and Mechanobiology of the Cell 4 Units
Terms offered: Spring 2019, Spring 2016, Spring 2015
This course applies methods of statistical continuum mechanics to subcellular biomechanical phenomena ranging from nanoscale (molecular) to microscale (whole cell and cell population) biological processes at the interface of mechanics, biology, and chemistry.

Objectives
Course Objectives: This course, which is open to senior undergraduate students or graduate students in diverse disciplines ranging from engineering to biology to chemistry and physics, is aimed at exposing students to subcellular biomechanical phenomena spanning scales from molecules to the whole cell.

Student Learning Outcomes: The students will develop tools and skills to (1) understand and analyze subcellular biomechanics and transport phenomena, and (2) ultimately apply these skills to novel biological and biomedical applications.

Rules & Requirements
Prerequisites: Math 54; Physics 7A; BioE102 or MEC85 or instructor's consent

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Alternative to final exam.
Instructor: Mofrad
Also listed as: MEC ENG C115

BIO ENG 113 Stem Cells and Technologies 4 Units
Terms offered: Fall 2015, Fall 2014, Fall 2013
This course will teach the main concepts and current views on key attributes of embryonic stem cells (ESC), will introduce theory of their function in embryonic development, methods of ESC derivation, propagation, and characterization, and will discuss currently developing stem cell technologies.

Rules & Requirements
Prerequisites: 10 and Biology 1A, or consent of instructor

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Conboy

Also listed as: MEC ENG C115
BIO ENG 114 Cell Engineering 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This course will teach the main concepts and current views on key attributes of animal cells (somatic, embryonic, pluripotent, germ-line; with the focus on mammalian cells), will introduce theory of the regulation of cell function, methods for deliberate control of cell properties and resulting biomedical and bioengineering technologies.

Objectives Outcomes

Course Objectives: The goal of this course to establish fundamental understanding of cell engineering technologies and of the key biological paradigms, upon which cell engineering is based, with the focus on biomedical applications of cell engineering.

Student Learning Outcomes: At the completion of this course students will understand how bioengineering technologies address the deliberate control of cell properties (and how this advances biomedicine); and students will learn the main concepts and current views on key attributes of animal cells (somatic, embryonic, pluripotent, germ-line; with the focus on mammalian cells).

Rules & Requirements

Prerequisites: Bio1A or Bio Eng 11; or consent of instructor

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 2 hours of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Conboy

BIO ENG 115 Tissue Engineering Lab 4 Units
Terms offered: Spring 2019, Fall 2018, Spring 2018
This class provides a conceptual and practical understanding of cell and tissue bioengineering that is vital for careers in medicine, biotechnology, and bioengineering. Students are introduced to cell biology laboratory techniques, including immunofluorescence, quantitative image analysis, protein quantification, protein expression, gene expression, and cell culture.

Objectives Outcomes

Course Objectives: The goal of this course to provide students with conceptual and practical understanding of cell and tissue bioengineering.

Student Learning Outcomes: At the completion of this course, students will learn key cellular bioengineering laboratory techniques, will develop a conceptual and theoretical understanding of the reliability and limitations of these techniques and will enhance their skills in quantitative data analysis, interpretation and integration.

Rules & Requirements

Prerequisites: BioEng 114 or 202, or BioE 11; or consent of instructor

Hours & Format

Fall and/or spring: 15 weeks - 9 hours of laboratory and 1 hour of lecture per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Alternative to final exam.
Instructor: Conboy

Tissue Engineering Lab: Read Less [-]
BIO ENG 116 Cell and Tissue Engineering 4 Units
Terms offered: Spring 2016, Spring 2015, Spring 2014
The goal of tissue engineering is to fabricate substitutes to restore tissue structure and functions. Understanding cell function in response to environmental cues will help us to establish design criteria and develop engineering tools for tissue fabrication. This course will introduce the basic concepts and approaches in the field, and train students to design and engineer biological substitutes.

Cell and Tissue Engineering:  Read More [+]

Objectives Outcomes

Course Objectives: (1) To introduce the basics of tissue engineering, including quantitative cell and tissue characterization, stem cells, cell-matrix interaction, cell migration, bioreactors, mechanical regulation, tissue preservation, and immuno-modulation/isolation; (2) To illustrate the cutting-edge research in tissue engineering; (3) To enhance the skills in analyzing and designing engineered tissue products.

Student Learning Outcomes: Students will be able to (1) use mathematical models to analyze cell functions (e.g., proliferation, apoptosis, migration) and mechanical property of tissues, (2) understand scientific and ethical issues of stem cells, (3) engineer natural matrix, biomaterials and drug delivery, (4) understand mass transport and design appropriate bioreactors, (5) understand clinical issues such as tissue preservation, immune responses, immunomodulation and immunoisolation, (6) apply the knowledge to engineering biological substitutes.

Rules & Requirements

Prerequisites: BioE 103 or equivalent, BioE 104

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Li

Cell and Tissue Engineering: Read Less [-]

BIO ENG C117 Structural Aspects of Biomaterials 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2016
This course covers the structure and mechanical functions of load bearing tissues and their replacements. Natural and synthetic load-bearing biomaterials for clinical applications are reviewed. Biocompatibility of biomaterials and host response to structural implants are examined. Quantitative treatment of biomechanical issues and constitutive relationships of tissues are covered in order to design biomaterial replacements for structural function. Material selection for load bearing applications including reconstructive surgery, orthopedics, dentistry, and cardiology are addressed. Mechanical design for longevity including topics of fatigue, wear, and fracture are reviewed. Case studies that examine failures of devices are presented.

Structural Aspects of Biomaterials:  Read More [+]

Rules & Requirements

Prerequisites: Biology 1A, Engineering 45, Civil and Environmental Engineering 130 or 130N or Bioengineering 102, and Engineering 190

Credit Restrictions: Students will receive no credit for Mechanical Engineering C117 after completing Mechanical Engineering C215/ Bioengineering C222.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam not required.

Instructor: Pruitt

Also listed as: MEC ENG C117

Structural Aspects of Biomaterials:  Read Less [-]
BIO ENG C118 Biological Performance of Materials 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2015
This course is intended to give students the opportunity to expand
their knowledge of topics related to biomedical materials selection and
design. Structure-property relationships of biomedical materials and their
interaction with biological systems will be addressed. Applications of the
concepts developed include blood-materials compatibility, biomimetic
materials, hard and soft tissue-materials interactions, drug delivery, tissue
engineering, and biotechnology.
Biological Performance of Materials: Read More [+]

Objectives Outcomes
Course Objectives: The course is separated into four parts spanning
the principles of synthetic materials and surfaces, principles of biological
materials, biological performance of materials and devices, and state-
of-the-art materials design. Students are required to attend class and
master the material therein. In addition, readings from the clinical, life
and materials science literature are assigned. Students are encouraged
to seek out additional reference material to complement the readings
assigned. A mid-term examination is given on basic principles (parts 1
and 2 of the outline). A comprehensive final examination is given as well.
The purpose of this course is to introduce students to problems
associated with the selection and function of biomaterials. Through
class lectures and readings in both the physical and life science
literature, students will gain broad knowledge of the criteria used to
select biomaterials, especially in devices where the material-tissue or
material-solution interface dominates performance. Materials used in
devices for medicine, dentistry, tissue engineering, drug delivery, and the
biotechnology industry will be addressed.

This course also has a significant design component (~35%). Students
will form small teams (five or less) and undertake a semester-long design
project related to the subject matter of the course. The project includes
the preparation of a paper and a 20 minute oral presentation critically
analyzing a current material-tissue or material-solution problem. Students
will be expected to design improvements to materials and devices to
overcome the problems identified in class with existing materials.

Student Learning Outcomes: Apply math, science & engineering
principles to the understanding of soft materials, surface chemistry, DLVO
theory, protein adsorption kinetics, viscoelasticity, mass diffusion, and
molecular (i.e., drug) delivery kinetics.

• Design experiments and analyze data from the literature in the context
  of the class design project.
Apply core concepts in materials science to solve engineering problems
related to the selection biomaterials, especially in devices where the
material-tissue or material-solution interface dominates performance.
Develop an understanding of the social, safety and medical
consequences of biomaterial use and regulatory issues associated with
the selection of biomaterials in the context of the silicone breast implant
controversy and subsequent biomaterials crisis.
Work independently and function on a team, and develop solid
communication skills (oral, graphic & written) through the class design
project.
• Understanding of the origin of surface forces and interfacial free energy,
  and how they contribute to the development of the biomaterial interface
  and ultimately biomaterial performance.

Rules & Requirements
Prerequisites: Engin 45; BioE 103 or equivalent; BioE 102 and BioE 104
recommended

Hours & Format

BIO ENG C119 Orthopedic Biomechanics 4 Units
Terms offered: Spring 2019, Fall 2017, Fall 2016
Statics, dynamics, optimization theory, composite beam theory, beam-
on-elastic foundation theory, Hertz contact theory, and materials
behavior. Forces and moments acting on human joints; composition
and mechanical behavior of orthopedic biomaterials; design/analysis of
artificial joint, spine, and fracture fixation prostheses; musculoskeletal
tissues including bone, cartilage, tendon, ligament, and muscle;
osteoporosis and fracture-risk predication of bones; and bone adaptation.
MATLAB-based project to integrate the course material.
Orthopedic Biomechanics: Read More [+]

Rules & Requirements
Prerequisites: Mechanical Engineering C85, Civil Engineering C30, or
Bioengineering 102, or equivalent; concurrent enrollment OK. Proficiency
in MatLab or equivalent. Prior knowledge of biology or anatomy is not
assumed

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of
laboratory per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Keaveny
Also listed as: MEC ENG C176
Orthopedic Biomechanics: Read Less [-]
BIO ENG 121 BioMEMS and Medical Devices
4 Units
Terms offered: Fall 2018, Spring 2018, Spring 2017
Biophysical and chemical principles of biomedical devices, bionanotechnology, bionanophotonics, and biomedical microelectromechanical systems (BioMEMS). Topics include basics of nano- and microfabrication, soft-lithography, DNA arrays, protein arrays, electrophoresis, telerobotics, transducers, microfluidic devices, biosensor, point of care diagnostics, lab-on-a-chip, drug delivery microsystems, clinical lab-on-a-chip, advanced biomolecular probes, etc.

Rules & Requirements
Prerequisites: Chemistry 3A; Physics 7A and 7B

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week
Summer:
6 weeks - 7.5 hours of lecture per week
8 weeks - 5.5 hours of lecture per week
10 weeks - 4.5 hours of lecture per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: L. Lee
BioMEMS and Medical Devices: Read Less [-]

BIO ENG 121L BioMems and BioNanotechnology Laboratory
4 Units
Terms offered: Spring 2019, Fall 2018, Fall 2016
Students will become familiar with BioMEMS and Lab-on-a-Chip research. Students will design and fabricate their own novel micro- or nano-scale device to address a specific problem in biotechnology using the latest micro- and nano-technological tools and fabrication techniques. This will involve an intensive primary literature review, experimental design, and quantitative data analysis. Results will be presented during class presentations and at a final poster symposium.

Objectives Outcomes
Course Objectives: Students will become familiar with research associated with BioMEMS and Lab-on-a-Chip technologies. Students will gain experience in using creative design to solve a technological problem. Students will learn basic microfabrication techniques. Working in engineering teams, students will learn how to properly characterize a novel device by choosing and collecting informative metrics. Students will design and carry out carefully controlled experiments that will result in the analysis of quantitative data.

Student Learning Outcomes: Students will learn how to critically read BioMEMS and Lab-on-a-Chip primary literature. Students will learn how to use AutoCAD software to design microscale device features. Students will gain hands-on experience in basic photolithography and soft lithography. Students will get experience with a variety of fluid loading interfaces and microscopy techniques. Students will learn how to design properly controlled quantitative experiments. Students will gain experience in presenting data to their peers in the form of powerpoint presentations and also at a poster symposium.

Rules & Requirements
Prerequisites: BioE 103 or equivalent, BioE 104
Credit Restrictions: Students will receive no credit for 121L after taking 221L.

Hours & Format
Fall and/or spring: 15 weeks - 6 hours of laboratory and 2 hours of lecture per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Alternative to final exam.
Instructor: D. Liepmann
BioMems and BioNanotechnology Laboratory: Read Less [-]
BIO ENG 124 Basic Principles of Drug Delivery 3 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This course focuses on providing students with the foundations needed to understand contemporary literature in drug delivery. Concepts in organic chemistry, biochemistry, and physical chemistry needed to understand current problems in drug delivery are emphasized.
Basic Principles of Drug Delivery: Read More [+]

Objectives Outcomes

Course Objectives: The goal of this course is to give students the ability to understand problems in drug delivery. Emphasis is placed on the design and synthesis of new molecules for drug delivery.

Student Learning Outcomes: At the completion of this course students should be able to design new molecules to solve drug delivery problems.

Rules & Requirements

Prerequisites: BioE 11 or Chem 3B; BioE 103, and BioE 104 (or courses equivalent to these)

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Murthy

Basic Principles of Drug Delivery: Read Less [-]

BIO ENG C125 Introduction to Robotics 4 Units
Terms offered: Fall 2017, Fall 2016, Fall 2015
An introduction to the kinematics, dynamics, and control of robot manipulators, robotic vision, and sensing. The course covers forward and inverse kinematics of serial chain manipulators, the manipulator Jacobian, force relations, dynamics, and control. It presents elementary principles on proximity, tactile, and force sensing, vision sensors, camera calibration, stereo construction, and motion detection. The course concludes with current applications of robotics in active perception, medical robotics, and other areas.
Introduction to Robotics: Read More [+]

Rules & Requirements

Prerequisites: EE 120 or equivalent, consent of instructor

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture, 1 hour of discussion, and 3 hours of laboratory per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Bajcsy

Formerly known as: Electrical Engineering C125/Bioengineering C125
Also listed as: EL ENG C106A

Introduction to Robotics: Read Less [-]
BIO ENG C125B Robotic Manipulation and Interaction 4 Units
Terms offered: Spring 2017, Spring 2016
This course is a sequel to Electrical Engineering C106A/Bioengineering C125, which covers kinematics, dynamics and control of a single robot. This course will cover dynamics and control of groups of robotic manipulators coordinating with each other and interacting with the environment. Concepts will include an introduction to grasping and the constrained manipulation, contacts and force control for interaction with the environment. We will also cover active perception guided manipulation, as well as the manipulation of non-rigid objects. Throughout, we will emphasize design and human-robot interactions, and applications to applications in manufacturing, service robotics, tele-surgery, and locomotion.

Robotic Manipulation and Interaction: Read More [+]

Rules & Requirements

Prerequisites: Electrical Engineering C106A/Bioengineering C125 or consent of the instructor

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture, 1 hour of discussion, and 3 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Alternative to final exam.

Instructors: Bajcsy, Sastry

Also listed as: EL ENG C106B

Robotic Manipulation and Interaction: Read Less [-]

BIO ENG 131 Introduction to Computational Molecular and Cell Biology 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
Topics include computational approaches and techniques to gene structure and genome annotation, sequence alignment using dynamic programming, protein domain analysis, RNA folding and structure prediction, RNA sequence design for synthetic biology, genetic and biochemical pathways and networks, UNIX and scripting languages, basic probability and information theory. Various “case studies” in these areas are reviewed; web-based computational biology tools will be used by students and programming projects will be given. Computational biology research connections to biotechnology will be explored.

Introduction to Computational Molecular and Cell Biology: Read More [+]

Objectives Outcomes

Course Objectives: To introduce the biological databases and file formats commonly used in computational biology. (2) To familiarize students with the use of Unix scripting languages in bioinformatics workflows. (3) To introduce common algorithms for sequence alignment, RNA structure prediction, phylogeny and clustering, along with fundamentals of probability, information theory and algorithmic complexity analysis.

Student Learning Outcomes: Students will be able to use knowledge from the lectures and lab sessions to write simple programs to parse bioinformatics file formats and execute basic algorithms, to analyze algorithmic complexity, to navigate and (for simple cases) set up biological databases containing biological data (including sequences, genome annotations and protein structures), and to use basic statistics to interpret results of compbio analyses.

Rules & Requirements

Prerequisites: BioE 11 or Bio 1A (may be taken concurrently); Math 53

Credit Restrictions: Students will receive no credit for 131 after taking 231.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1.5 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Holmes

Introduction to Computational Molecular and Cell Biology: Read Less [-]
BIO ENG 132 Genetic Devices 4 Units
Terms offered: Spring 2018, Fall 2014, Fall 2013
This senior-level course is a comprehensive survey of genetic devices. These DNA-based constructs are comprised of multiple "parts" that together encode a higher-level biological behavior and perform useful human-defined functions. Such constructs are the engineering target for most projects in synthetic biology. Included within this class of constructs are genetic circuits, sensors, biosynthetic pathways, and microbiological functions.

Genetic Devices: Read More [+]

Objectives Outcomes

Course Objectives: (1) To introduce the basic biology and engineering principles for constructing genetic devices including biochemical devices, microbiological devices, genetic circuits, eukaryotic devices, and developmental devices, (2) To familiarize students with current literature examples of genetic devices and develop literature searching skills; (3) To develop the students' ability to apply computational tools to the design of genetic devices.

Student Learning Outcomes: Students will be able to (1) use mathematical models to describe the dynamics of genetic devices, (2) comprehend and evaluate publications related to any type of genetic device, (3) perform a thorough literature search, (4) evaluate the technical plausibility of a proposed genetic device, (5) analyze a design challenge and propose a plausible solution to it in the form of a genetic device, and (6) assess any ethical or safety issues associated with a proposed genetic device.

Rules & Requirements

Prerequisites: Computer Science 61A; Math 53 & 54; Chemistry 3A; Chem 3B or BioE 11; BioE 103 or equivalent

Credit Restrictions: Students will receive no credit for 132 after taking 232.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Anderson

Genetic Devices: Read Less [-]

BIO ENG 133 Biomolecular Engineering 3 Units
Terms offered: Prior to 2007
This is an introductory course of biomolecular engineering and is required for all CBE graduate students. Undergraduates with knowledge of thermodynamics and transport are also welcome. The topics include structures, functions, and dynamics of biomolecules; molecular tools in biotechnology; metabolic and signaling networks in cellular engineering; and synthetic biology and biomedical engineering applications.

Biomolecular Engineering: Read More [+]

Objectives Outcomes

Course Objectives: Students are expected to become familiar with the terminologies, molecules, and mechanisms, i.e., the language of biomolecular engineering. At end of this course, you are expected to be able to analyze and critique modern literature in related research areas.

Student Learning Outcomes: Students will be able to (1) understand the biochemical basis for protein folding and enzymatic function, (2) mathematically analyze enzyme function, either individually or as part of a metabolic pathway, (3) engineer novel enzymes using rational, computational, and directed evolution based approaches, (4) understand principles of metabolic engineering and synthetic biology, (5) understand the dynamics and mechanisms of cellular signal transduction, and (6) understand principles for engineering cellular signaling and function.

Rules & Requirements

Prerequisites: Bioengineering 104 or Chemical and Biomolecular Engineering 150A-150B or consent of instructor. A course in statistical mechanics and/or thermodynamics is recommended

Credit Restrictions: Students will receive no credit for Bioengineering 133 after completing Chemical Engineering C274, Molecular and Cell Biology C274 or Bioengineering C233.

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Schaffer

Biomolecular Engineering: Read Less [-]
**BIO ENG 134 Genetic Design Automation 4 Units**

**Terms offered:** Fall 2018, Fall 2017

Genetic Design Automation is the use of software to design and manage genetics experiments. This course introduces the interface between object-oriented programming and wetlab synthetic biology in a hands-on manner. Through a series of programming assignments, each student will build a computer program that automatically designs experiments starting from a formal specification. They will then independently build a new software module of their own design to augment the basic platform.

**Objectives Outcomes**

**Course Objectives:**
1. To develop the skill of translating experimental design into computer code,
2. Develop familiarity with state-of-the-art infrastructure for wetlab automation,
3. Develop proficiency in software development

**Student Learning Outcomes:**
- students will be able to
  1. Describe molecular biology entities and operations in terms of data structures,
  2. Develop moderately-sized computer programs,
  3. Write tests and benchmarking suites for biological algorithms
  4. Explore different algorithmic approaches to problems and assess their relative merits and efficiencies,
  5. Develop proficiency in conceiving and implementing software projects of their own design as they relate to biological problems

**Rules & Requirements**

**Prerequisites:**
- Computer Science 61B
- Bioengineering 11
- Bioengineering 103 or equivalent

**Hours & Format**

- 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Instructor:**
- J. Christopher Anderson

**BIO ENG 135 Frontiers in Microbial Systems Biology 4 Units**

**Terms offered:** Spring 2019, Spring 2017, Fall 2009

This course is aimed at graduate and advanced undergraduate students from the (bio)engineering and chemo-physical sciences interested in a research-oriented introduction to current topics in systems biology. Focusing mainly on two well studied microbiological model systems—the chemotaxis network and Lambda bacteriophage infection—the class systematically introduces key concepts and techniques for biological network deduction, modelling, analysis, evolution, and synthetic network design. Students analyze the impact of approaches from the quantitative sciences—such as deterministic modelling, stochastic processes, statistics, non-linear dynamics, control theory, information theory, graph theory, etc.—on understanding biological processes, including (stochastic) gene regulation, signalling, network evolution, and synthetic network design. The course aims to identify unsolved problems and discusses possible novel approaches while encouraging students to develop ideas to explore new directions in their own research.

**Rules & Requirements**

**Prerequisites:**
- Upper division standing with background in differential equations and probability.
- Coursework in molecular and cell biology or biochemistry recommended

**Credit Restrictions:**
- Students will receive no credit for 135 after taking 235.

**Hours & Format**

- 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Instructors:**
- Arkin, Bischofs-Pfeifer, Wolf

**Subject/Course Level:**
- Bioengineering/Undergraduate

**Grading/Final exam status:**
- Letter grade. Final exam required.

**Instructors:**
- Arkin, Bischofs-Pfeifer, Wolf

**Frontiers in Microbial Systems Biology:** Read Less [-]
**BIO ENG C136L Laboratory in the Mechanics of Organisms 3 Units**


Introduction to laboratory and field study of the biomechanics of animals and plants using fundamental biomechanical techniques and equipment. Course has a series of rotations involving students in experiments demonstrating how solid and fluid mechanics can be used to discover the way in which diverse organisms move and interact with their physical environment. The laboratories emphasize sampling methodology, experimental design, and statistical interpretation of results. Latter third of course devoted to independent research projects. Written reports and class presentation of project results are required.

**Rules & Requirements**

**Prerequisites:** Integrative Biology 135 or consent of instructor; for Electrical Engineering and Computer Science students, Electrical Engineering 105, 120 or Computer Science 184

**Credit Restrictions:** Students will receive no credit for C135L after taking 135L.

**Hours & Format**

Fall and/or spring: 15 weeks - 6 hours of laboratory, 1 hour of discussion, and 1 hour of fieldwork per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Formerly known as:** Integrative Biology 135L

**Also listed as:** EL ENG C145O/INTEGBI C135L

Laboratory in the Mechanics of Organisms: Read Less [-]

**BIO ENG C137 Designing for the Human Body 4 Units**

Terms offered: Fall 2018, Fall 2017

The course provides project-based learning experience in understanding product design, with a focus on the human body as a mechanical machine. Students will learn the design of external devices used to aid or protect the body. Topics will include forces acting on internal materials (e.g., muscles and total replacement devices), forces acting on external materials (e.g., prosthetics and crash pads), design/analysis of devices aimed to improve or fix the human body, muscle adaptation, and soft tissue injury. Weekly laboratory projects will incorporate EMG sensing, force plate analysis, and interpretation of data collection (e.g., MATLAB analysis) to integrate course material to better understand contemporary design/analysis/problems.

**Objectives Outcomes**

**Course Objectives:** The purpose of this course is twofold:

- to learn the fundamental concepts of designing devices to interact with the human body;
- to enhance skills in mechanical engineering and bioengineering by analyzing the behavior of various complex biomedical problems;
- To explore the transition of a device or discovery as it goes from “benchtop to bedside”.

**Student Learning Outcomes:** RELATIONSHIP OF THE COURSE TO ABET PROGRAM OUTCOMES

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(l) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Working knowledge of design considerations for creating a device to protect or aid the human body, force transfer and distribution, data analysis, and FDA approval process for new devices. Understanding of basic concepts in orthopaedic biomechanics and the ability to apply the appropriate engineering concepts to solve realistic biomechanical problems, knowing clearly the assumptions involved. Critical analysis of current literature and technology.

**Rules & Requirements**

**Prerequisites:** Proficiency in MatLab or equivalent. Prior knowledge of biology or anatomy is not assumed. Physics 7A, Math 1A and 1B

**Credit Restrictions:** There will be no credit given for MEC ENG C178 / BIO ENG C137 after taking MEC ENG 178.

**Hours & Format**

Fall and/or spring: 15 weeks - 1-3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate
BIO ENG 140L Synthetic Biology Laboratory
4 Units
Terms offered: Spring 2019, Fall 2015, Spring 2015
This laboratory course is designed as an introduction to research in synthetic biology, a ground-up approach to genetic engineering with applications in bioenergy, healthcare, materials science, and chemical production. In this course, we will design and execute a real research project. Each student will be responsible for designing and constructing components for the group project and then performing experiments to analyze the system. In addition to laboratory work, we will have lectures on methods and design concepts in synthetic biology including an introduction to BioBricks, gene synthesis, computer modeling, directed evolution, practical molecular biology, and biochemistry.
Synthetic Biology Laboratory: Read More [+]
Objectives Outcomes

Course Objectives:
- Designing and interpreting biological experiments
- Learning how to plan, coordinate, and implement a genetic engineering project in a group format
- To master the wetlab techniques of synthetic biology

Student Learning Outcomes:
- Students will be able to examine analytical data, interpret controls, and make decisions about next steps.
- Students will be able to perform synthetic biology experiments including reagent preparation, DNA manipulation, analytical methods, and microbiological techniques.
- Students will be able to understand responsible conduct expectations for wetlab experimentalists.
- Students will be able to understand the techniques and protocols used in synthetic biology.
- Students will be able to work within a team and develop communication skills.

Rules & Requirements

Prerequisites: BioE 11 or Bio 1A

Hours & Format

Fall and/or spring: 15 weeks - 2 hours of lecture and 6 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Anderson

Synthetic Biology Laboratory: Read Less [-]

BIO ENG 143 Computational Methods in Biology
4 Units
Terms offered: Fall 2011, Fall 2010, Fall 2009
An introduction to biophysical simulation methods and algorithms, including molecular dynamics, Monte Carlo, mathematical optimization, and "non-algorithmic" computation such as neural networks. Various case studies in applying these areas in the areas of protein folding, protein structure prediction, drug docking, and enzymatics will be covered. Core Specialization: Core B (Informatics and Genomics); Core D (Computational Biology); BioE Content: Biological.
Computational Methods in Biology: Read More [+]

Rules & Requirements

Prerequisites: Math 53 and Math 54; programming experience preferred but not required

Hours & Format

Fall and/or spring: 15 weeks - 3 hours of lecture, 1 hour of discussion, and 2 hours of laboratory per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Head-Gordon

Computational Methods in Biology: Read Less [-]
BIO ENG 144 Introduction to Protein Informatics 4 Units
Terms offered: Spring 2017, Fall 2008, Fall 2007
This course will introduce students to the bioinformatics algorithms used by biologists to identify homologs, construct multiple sequence alignments, predict protein structure, estimate phylogenetic trees, identify orthologs, predict protein-protein interaction, and build hidden Markov models. The focus is on the algorithms used, and on the sources of various types of errors in these methods.

Course Objectives:
This course is designed to provide a theoretical framework for protein sequence and structure analysis using bioinformatics software tools. Students completing this course will be prepared for subsequent in-depth studies in bioinformatics, for algorithm development, and for the use of bioinformatics methods for biological discovery. It is aimed at two populations: students in the life sciences who need to become expert users of bioinformatics tools, and students in engineering and mathematics/computer science who wish to become the developers of the next generation of bioinformatics methods. As virtually all the problems in this field are very complex, there are many opportunities for research and development of new methods.

Student Learning Outcomes:
Students completing this course are likely to find several potential areas of research of interest, which they may want to work on as independent study projects during undergraduate work, or take on as Master's or Ph.D. thesis topics for advanced work.

Rules & Requirements
Prerequisites:
Prior coursework in algorithms. No prior coursework in biology is required. This course includes no programming projects and prior experience in programming is not required.

Credit Restrictions: BioE 244 or BioE C244L/PMB C244

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Sjolander
Formerly known as: Bioengineering C144L/Plant and Microbial Biology C144

Introduction to Protein Informatics: Read More [+]

BIO ENG 144L Protein Informatics Laboratory 3 Units
Terms offered: Fall 2008
This course is intended to provide hands-on experience with a variety of bioinformatics tools, web servers, and databases that are used to predict protein function and structure. This course will cover numerous bioinformatics tasks including: homolog detection using BLAST and PSI-BLAST, hidden Markov model construction and use, multiple sequence alignment, phylogenetic tree construction, ortholog identification, protein structure prediction, active site prediction, cellular localization, protein-protein interaction and phylogenomic analysis. Some minimal programming/scripting skills (e.g., Perl or Python) are required to complete some of the labs.

Course Objectives:
This course is designed to provide a theoretical framework for protein sequence and structure analysis using bioinformatics software tools. Students completing this course will be prepared for subsequent in-depth studies in bioinformatics, for algorithm development, and for the use of bioinformatics methods for biological discovery. It is aimed at two populations: students in the life sciences who need to become expert users of bioinformatics tools, and students in engineering and mathematics/computer science who wish to become the developers of the next generation of bioinformatics methods. As virtually all the problems in this field are very complex, there are many opportunities for research and development of new methods.

Student Learning Outcomes:
Students completing this course are likely to find several potential areas of research of interest, which they may want to work on as independent study projects during undergraduate work, or take on as Master's or Ph.D. thesis topics for advanced work.

Rules & Requirements
Prerequisites:
One upper-division course in molecular biology or biochemistry (e.g., MCB C100A/Chem C130 or equivalent). Python programming (e.g., CS 61A) and experience using command-line tools in a Unix environment.

Credit Restrictions: Bio Eng 244L or Bio Eng C244L/PMB C244L

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of laboratory and 2 hours of lecture per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Sjolander
Formerly known as: Bioengineering C144L/Plant and Microbial Biology C144

Protein Informatics Laboratory: Read Less [-]

Introduction to Protein Informatics: Read Less [-]
**BIO ENG 145 Intro to Machine Learning in Computational Biology 4 Units**

Terms offered: Fall 2017

This course will review the fundamentals of Data Science and data mining techniques. We will begin by reviewing Data Science across the disciplines, including guest lectures from data scientists on campus. As the semester progresses, we will focus increasingly on data science techniques in computational biology and bioinformatics, illustrating major methods and issues from these fields. Finally, we will discuss ethical issues related to data from biomedical research and genomics.

**Intro to Machine Learning in Computational Biology: Read More [+]**

**Objectives Outcomes**

**Course Objectives:** This course aims to equip students with a foundational understanding of machine learning techniques used in genomics and computational biology. Desired Course Outcomes: Students completing this course should have stronger programming skills, the ability to apply simple machine learning techniques to complex biosequence and genomics data, and an understanding of some of the challenges in genomics and bioinformatics.

**Student Learning Outcomes:** Students completing this course should have stronger programming skills, the ability to apply simple machine learning techniques to complex biosequence and genomics data, and an understanding of some of the challenges in genomics and bioinformatics.

**Rules & Requirements**

**Prerequisites:** CS61B, CS70 or Math 55; CS170 or STAT 132 or STAT 133 (may be taken concurrently); BioE 144L (may be taken concurrently)

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture and 3 hours of laboratory per week

**Additional Details**

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: K. Sjolander

**Intro to Machine Learning in Computational Biology: Read Less [-]**

**BIO ENG C145L Introductory Electronic Transducers Laboratory 3 Units**

Terms offered: Fall 2014, Fall 2013, Fall 2012

Laboratory exercises exploring a variety of electronic transducers for measuring physical quantities such as temperature, force, displacement, sound, light, ionic potential; the use of circuits for low-level differential amplification and analog signal processing; and the use of microcomputers for digital sampling and display. Lectures cover principles explored in the laboratory exercises; construction, response and signal to noise of electronic transducers and actuators; and design of circuits for sensing and controlling physical quantities.

**Introductory Electronic Transducers Laboratory: Read More [+]**

**Hours & Format**

Fall and/or spring: 15 weeks - 2 hours of lecture and 3 hours of laboratory per week

**Additional Details**

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Derenzo

Also listed as: EL ENG C145L

**Introductory Electronic Transducers Laboratory: Read Less [-]**

**BIO ENG C145M Introductory Microcomputer Interfacing Laboratory 3 Units**

Terms offered: Spring 2013, Spring 2012, Spring 2011

Laboratory exercises constructing basic interfacing circuits and writing 20-100 line C programs for data acquisition, storage, analysis, display, and control. Use of the IBM PC with microprogrammable digital counter/timer, parallel I/O port. Circuit components include anti-aliasing filters, the S/H amplifier, A/D and D/A converters. Exercises include effects of aliasing in periodic sampling, fast Fourier transforms of basic waveforms, the use of the Hanning filter for leakage reduction, Fourier analysis of the human voice, digital filters, and control using Fourier deconvolution. Lectures cover principles explored in the lab exercises and design of microcomputer-based systems for data acquisitions, analysis and control.

**Introductory Microcomputer Interfacing Laboratory: Read More [+]**

**Rules & Requirements**

**Prerequisites:** EE 16A & 16B

**Hours & Format**

Fall and/or spring: 15 weeks - 2 hours of lecture and 3 hours of laboratory per week

**Additional Details**

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Final exam required.

Instructor: Derenzo

Also listed as: EL ENG C145M

**Introductory Microcomputer Interfacing Laboratory: Read Less [-]**
BIO ENG 147 Principles of Synthetic Biology
4 Units
Terms offered: Fall 2018, Fall 2016, Fall 2015
The field of synthetic biology is quickly emerging as potentially one of
the most important and profound ways by which we can understand
and manipulate our physical world for desired purposes. In this course,
the field and its natural scientific and engineering basis are introduced.
Relevant topics in cellular and molecular biology and biophysics,
dynamical and engineering systems, and design and operation of natural
and synthetic circuits are covered in a concise manner that then allows
the student to begin to design new biology-based systems.
Principles of Synthetic Biology: Read More [+]

Objectives
Course Objectives: (1) To introduce the basics of Synthetic Biology,
including quantitative cellular network characterization and modeling, (2)
to introduce the principles of discovery and genetic factoring of useful
cellular activities into reusable functions for design, (3) to inculcate the
principles of biomolecular system design and diagnosis of designed
systems, and (4) to illustrate cutting-edge applications in Synthetic
Biology and to enhance skill in analyzing and designing synthetic
biological applications.

Student Learning Outcomes: The goals of this course are to enable
students to: (1) design simple cellular circuitry to meet engineering
specification using both rational/model-based and library-based
approaches, (2) design experiments to characterize and diagnose
operation of natural and synthetic biomolecular network functions, and (3)
understand scientific, safety and ethical issues of synthetic biology.

Rules & Requirements
Prerequisites: Math 53 and 54; BioE 103 or equivalent or consent of
instructor
Credit Restrictions: Students will receive no credit for 147 after taking
247.

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of
discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Alternative to final exam.
Instructor: Arkin

Principles of Synthetic Biology: Read Less [-]

BIO ENG 148 Bioenergy and Sustainable
Chemical Synthesis: Metabolic Engineering
and Synthetic Biology Approaches 3 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This course will cover metabolic engineering and the various synthetic
biology approaches for optimizing pathway performance. Use of
metabolic engineering to produce biofuels and general "green
technology" will be emphasized since these aims are currently pushing
these fields. The course is meant to be a practical guide for metabolic
engineering and the related advances in synthetic biology as well the
related industrial research and opportunities.
Bioenergy and Sustainable Chemical Synthesis: Metabolic Engineering
and Synthetic Biology Approaches: Read More [+]

Objectives
Course Objectives: (1) Learn the common engineered metabolic
pathways for biofuel biosynthesis
(2) analytical methods
(3) synthetic biology approaches
(4) Industry technologies and opportunities

Student Learning Outcomes: Students will learn (1) the common
pathways used for biofuel synthesis and framework for the biosynthesis
of specialty chemicals, (2) analytical methods for quantitative
measurements of metabolic pathways, (3) synthetic biology approaches
for increasing overall pathway performance, and how to (4) utilize
available online resources for culling information from large data sources.

Rules & Requirements
Prerequisites: Chem 3A, BioE 103 or equivalent

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Dueber

Bioenergy and Sustainable Chemical Synthesis: Metabolic Engineering
and Synthetic Biology Approaches: Read Less [-]
BIO ENG 150 Introduction of Bionanoscience and Bionanotechnology 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This course is intended for the bioengineering or engineering undergraduate students interested in acquiring a background in recent development of bio-nanomaterials and bio-nanotechnology. The emphasis of the class is to understand the properties of biological basis building blocks, their assembly principles in nature, and their application to build functional materials and devices.

Introduction of Bionanoscience and Bionanotechnology: Read More [+]

Objectives Outcomes

Course Objectives: I. Basic building blocks and governing forces:
This part is intended to enhance the understanding of the structures and properties of biological basic building blocks and their governing forces to assemble the biological materials. This part covers the chemical structures of amino acids, ribonucleic acids, hydrocarbonates, and lipids, and their physical properties depending on the chemical and physical structures. In addition, governing forces (hydrogen bonding, ionic interaction, van der Waals interaction, hydrophobic interactions, etc) to assemble the basic building blocks to form nanostructures will be covered. Tools and methodologies to analyze the chemical structure of the molecules will be introduced. Quantitative analysis of the properties of biological basic building blocks will also be addressed.

II. Case study of the molecular level structures of biological materials.
This part is intended to study the examples of biological molecules to enhance the assembly principle of biological materials, including collagen, keratins, spider webs, silks, bio-adhesives as protein based robust materials, bones, sea shells, diatoms, sponges, and, other biomimetics as hierarchical nanostructures, and butterfly wings and insect eyes, other periodic structures for optical applications. Through the case study, we will learn how natural materials are designed to solve the challenging problem to be faced in the natural environments and exploit their design principle to develop novel functional materials and devices.

III. Case study of the artificial nanomaterials and devices inspired by biological nature. This part is intended to enhance understanding the recently developed nanostructures and devices to mimic the natural biological materials and organisms. Hybrid functional nanomaterials and devices, such as biological basic building blocks conjugated with inorganic nanocomponents, such as quantum dots, nanowires, nanotubes will be discussed to fabricate various devices including, biosensor, bio-nano electronic materials and devices, bio-computing. Nano medicine and bio imaging will also be covered.
The goal is for the bioengineering students to gain sufficient chemical and physical aspects of biological materials through the case study of spider webs, silks, sea shells, diatoms, bones, and teeth, as well as recently developed self-assembled nanostructures inspired by nature.

Student Learning Outcomes: This course is intended for the undergraduate students interested in acquiring a background of recent development of bio-nanomaterials and bio-nanotechnology focused on the materials point of view. Through this course, students will understand the assembly principle of biological materials and their application in bio-nanotechnology.

Rules & Requirements
Prerequisites: BioE 11 or Biology 1A, Chem 1A

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

BIO ENG 151 Micro/Nanofluidics for Bioengineering and Lab-On-A-Chip 4 Units
Terms offered: Spring 2015, Spring 2014, Spring 2013
Introduction and in-depth treatment of theory relevant to fluid flow in microfluidic and nanofluidic systems supplemented by critical assessment of recent applications drawn from the literature. Topics include low Reynolds Number flow, mass transport including diffusion phenomena, and emphasis on electrokinetic systems and bioanalytical applications of said phenomena.

Micro/Nanofluidics for Bioengineering and Lab-On-A-Chip: Read More [+]

Objectives Outcomes

Course Objectives: We will study mass and momentum transport phenomena of microscale and nanoscale flow devices. Throughout the course, we will place an emphasis on bioanalytical microfluidic system applications where electrophoresis, electroosmosis, molecular diffusion, and/or Brownian motion effects dominate. Successful completion of the course will prepare students to design micro/nanofluidic engineering solutions, as well as critically assess academic and industrial developments in these areas.

The course is an introduction to the physicochemical dynamics associated with fluid flow in nanoscale and microscale devices for graduate students and advanced undergraduate students. The course has been created in response to the active field of microfluidics and nanofluidics, as well as the associated interest from industry, government, and academic research groups. The course provides an theoretical treatment of micro/nanofluidic phenomena that complements the well-established laboratory and research content offered in the Department.

Student Learning Outcomes: 1. To introduce students to the governing principles of fluid flow in microfluidic and nanofluidic regimes, with emphasis on phenomena relevant to bioanalytical devices.
2. To provide students with an understanding of scaling laws that define the performance of microfluidic and nanofluidic systems.
3. To provide students with a detailed investigation of applications that do and do not benefit from miniaturization.
4. To give students adequate didactic background for critical assessment of literature reports and conference presentations regarding advances in the topical areas of microfluidics and nanofluidics.

Rules & Requirements
Prerequisites: BioE 11 or Chem 3B, BioE 104 or ME 106 or consent of instructor

Credit Restrictions: Students will receive no credit for 151 after taking 251.

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.

Instructor: Herr
Micro/Nanofluidics for Bioengineering and Lab-On-A-Chip: Read Less [-]
BIO ENG 163 Principles of Molecular and Cellular Biophotonics 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This course provides undergraduate and graduate bioengineering students with an opportunity to increase their knowledge of topics in the emerging field of biophotonics with an emphasis on fluorescence spectroscopy, biosensors and devices for optical imaging and detection of biomolecules. This course will cover the photophysics and photochemistry of organic molecules, the design and characterization of biosensors and their applications within diverse environments.

Rules & Requirements
Prerequisites: 102 or consent of instructor, Chemistry 3A, and Physics 7B

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam not required.
Instructor: Marriott

Principles of Molecular and Cellular Biophotonics: Read Less [-]

BIO ENG 163L Molecular and Cellular Biophotonics Laboratory 4 Units
Terms offered: Spring 2019, Spring 2018, Spring 2017
This course provides undergraduate and graduate bioengineering students with an opportunity to acquire essential experimental skills in fluorescence spectroscopy and the design, evaluation, and optimization of optical biosensors for quantitative measurements of proteins and their targets. Groups of students will be responsible for the research, design, and development of a biosensor or diagnostic device for the detection, diagnosis, and monitoring of a specific biomarker(s).

Rules & Requirements
Prerequisites: Bioengineering 163 and ok to take concurrently
Credit Restrictions: Students will receive no credit for Bioengineering 163L after taking Bioengineering 263L.

Hours & Format
Fall and/or spring: 15 weeks - 6 hours of laboratory and 2 hours of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Marriott

Molecular and Cellular Biophotonics Laboratory: Read Less [-]

BIO ENG 164 Optics and Microscopy 4 Units
Terms offered: Fall 2010, Fall 2009, Fall 2008
This course teaches fundamental principles of optics and examines contemporary methods of optical microscopy for cells and molecules. Students will learn how to design simple optical systems, calculate system performance, and apply imaging techniques including transmission, reflection, phase, and fluorescence microscopy to investigate biological samples. The capabilities of optical microscopy will be compared with complementary techniques including electron microscopy, coherence tomography, and atomic force microscopy. Students will also be responsible for researching their final project outside of class and presenting a specific application of modern microscopy to biological research as part of an end-of-semester project.

Rules & Requirements
Prerequisites: Physics 7A-7B or 8A-8B or equivalent introductory physics course

Hours & Format
Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam required.
Instructor: Fletcher

Optics and Microscopy: Read Less [-]
**BIO ENG C165 Medical Imaging Signals and Systems 4 Units**

Terms offered: Fall 2018, Fall 2017, Fall 2016

Biomedical imaging is a clinically important application of engineering, applied mathematics, physics, and medicine. In this course, we apply linear systems theory and basic physics to analyze X-ray imaging, computerized tomography, nuclear medicine, and MRI. We cover the basic physics and instrumentation that characterizes medical image as an ideal perfect-resolution image blurred by an impulse response. This material could prepare the student for a career in designing new medical imaging systems that reliably detect small tumors or infarcts.

Medical Imaging Signals and Systems: Read More [+]

**Rules & Requirements**

**Prerequisites:** Electrical Engineering 16A and 16B

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture and 1 hour of discussion per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructor:** Conolly

**Also listed as:** EL ENG C145B

Medical Imaging Signals and Systems: Read Less [-]

**BIO ENG 168L Practical Light Microscopy 3 Units**

Terms offered: Fall 2017, Spring 2015, Fall 2013

This laboratory course is designed for students interested in obtaining practical hands-on training in optical imaging and instrumentation. Using a combination of lenses, cameras, and data acquisition equipment, students will construct simple light microscopes that introduce basic concepts and limitations important in biomedical optical imaging. Topics include compound microscopes, Kohler illumination, Rayleigh two-point resolution, image contrast including dark-field and fluorescence microscopy, and specialized techniques such as fluorescence recovery after photobleaching (FRAP). Intended for students in both engineering and the sciences, this course will emphasize applied aspects of optical imaging and provide a base of practical skill and reference material that students can leverage in their own research or in industry.

Practical Light Microscopy: Read More [+]

**Hours & Format**

Fall and/or spring: 15 weeks - 2 hours of lecture and 3 hours of laboratory per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructor:** Fletcher

**Also listed as:** CHEM C138/CHM ENG C195A/PLANTBI C124

Practical Light Microscopy: Read Less [-]

**BIO ENG C181 The Berkeley Lectures on Energy: Energy from Biomass 3 Units**

Terms offered: Fall 2015, Fall 2014, Fall 2013

After an introduction to the different aspects of our global energy consumption, the course will focus on the role of biomass. The course will illustrate how the global scale of energy guides the biomass research. Emphasis will be placed on the integration of the biological aspects (crop selection, harvesting, storage and distribution, and chemical composition of biomass) with the chemical aspects to convert biomass to energy. The course aims to engage students in state-of-the-art research.

The Berkeley Lectures on Energy: Energy from Biomass: Read More [+]

**Rules & Requirements**

**Prerequisites:** Chemistry 1B or Chemistry 4B, Mathematics 1B, Biology 1A

**Repeat rules:** Course may be repeated for credit under special circumstances: Repeatable when topic changes with consent of instructor.

**Hours & Format**

Fall and/or spring: 15 weeks - 3 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructors:** Bell, Blanch, Clark, Smit, C. Somerville

**Also listed as:** CHEM C138/CHM ENG C195A/PLANTBI C124

The Berkeley Lectures on Energy: Energy from Biomass: Read Less [-]

**BIO ENG 190 Special Topics in Bioengineering 1 - 4 Units**

Terms offered: Spring 2019, Fall 2017, Fall 2016

This course covers current topics of research interest in bioengineering. The course content may vary from semester to semester.

Special Topics in Bioengineering: Read More [+]

**Rules & Requirements**

**Prerequisites:** Consent of instructor

**Repeat rules:** Course may be repeated for credit without restriction.

**Hours & Format**

Fall and/or spring: 15 weeks - 1-4 hours of lecture per week

**Additional Details**

**Subject/Course Level:** Bioengineering/Undergraduate

**Grading/Final exam status:** Letter grade. Final exam required.

**Instructor:** Fletcher

Special Topics in Bioengineering: Read Less [-]
BIO ENG 192 Senior Design Projects 4 Units
Terms offered: Fall 2018, Fall 2017, Fall 2016
This semester-long course introduces students to bioengineering project-based learning in small teams, with a strong emphasis on need-based solutions for real medical and research problems through prototype solution selection, design, and testing. The course is designed to provide a "capstone" design experience for bioengineering seniors. The course is structured around didactic lectures, and a textbook, from which assigned readings will be drawn, and supplemented by additional handouts, readings, and lecture material. Where appropriate, the syllabus includes guest lectures from clinicians and practicing engineers from academia and industry. The course includes active learning through organized activities, during which teams will participate in exercises meant to reinforce lecture material through direct application to the team design project.

Rules & Requirements
Prerequisites: Senior standing
Hours & Format
Fall and/or spring: 15 weeks - 2 hours of lecture and 2 hours of discussion per week
Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam not required.
Instructor: Herr

BIO ENG H194 Honors Undergraduate Research 3 or 4 Units
Terms offered: Fall 2018, Spring 2016, Fall 2015
Supervised research. Students who have completed 3 or more upper division courses may pursue original research under the direction of one of the members of the staff. May be taken a second time for credit only. A final report or presentation is required. A maximum of 4 units of this course may be used to fulfill the research or technical elective requirement or in the Bioengineering program.

Rules & Requirements
Prerequisites: Upper division technical GPA 3.3 or higher and consent of instructor and adviser
Repeat rules: Course may be repeated for credit up to a total of 8 units.
Hours & Format
Fall and/or spring: 15 weeks - 3-4 hours of independent study per week
Summer:
8 weeks - 1.5-7.5 hours of independent study per week
10 weeks - 1.5-9 hours of independent study per week
Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Letter grade. Final exam not required.
Honors Undergraduate Research: Read Less [-]
BIO ENG 195 Bioengineering Department Seminar 1 Unit
Terms offered: Prior to 2007
This weekly seminar series invites speakers from the bioengineering community, as well as those in related fields, to share their work with our department and other interested parties on the Berkeley campus. The series includes our annual Bioengineering Distinguished Lecture and Rising Star lecture.
Bioengineering Department Seminar: Read More [+]

Objectives Outcomes

Course Objectives:
• To introduce students to bioengineering research as it is performed at Berkeley and at other institutions
• To give students opportunities to connect their own work to work in the field overall
• To give students an opportunity to meet with speakers who can inform and contribute to their post-graduation career paths

Student Learning Outcomes: To introduce students to the breadth of bioengineering research, both here at Berkeley and at other institutions, and help them to connect their work here at Berkeley to the field overall.

Rules & Requirements

Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 1 hour of seminar per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.

Instructor: Faculty

Bioengineering Department Seminar: Read Less [-]

BIO ENG 196 Undergraduate Design Research 4 Units
Terms offered: Fall 2018, Fall 2017, Summer 2016 10 Week Session
Supervised research. This course will satisfy the Senior Bioengineering Design project requirement. Students with junior or senior status may pursue research under the direction of one of the members of the staff.
May be taken a second time for credit only. A final report or presentation is required.
Undergraduate Design Research: Read More [+]

Rules & Requirements

Prerequisites: Junior or senior status, consent of instructor and faculty adviser
Repeat rules: Course may be repeated for credit up to a total of 8 units.

Hours & Format

Fall and/or spring: 15 weeks - 4 hours of independent study per week
Summer: 10 weeks - 6 hours of independent study per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Letter grade. Alternative to final exam.

Undergraduate Design Research: Read Less [-]

BIO ENG 198 Directed Group Study for Advanced Undergraduates 1 - 4 Units
Terms offered: Spring 2019, Fall 2018, Spring 2018
Group study of a selected topic or topics in bioengineering, usually relating to new developments.
Directed Group Study for Advanced Undergraduates: Read More [+]

Rules & Requirements

Prerequisites: Upper division standing and good academic standing. (2.0 grade point average and above)
Credit Restrictions: Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog.
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format

Fall and/or spring: 15 weeks - 1-4 hours of directed group study per week
Summer:
6 weeks - 2.5-10 hours of directed group study per week
8 weeks - 1.5-7.5 hours of directed group study per week

Additional Details

Subject/Course Level: Bioengineering/Undergraduate

Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.

Directed Group Study for Advanced Undergraduates: Read Less [-]
BIO ENG 199 Supervised Independent Study
1 - 4 Units
Terms offered: Fall 2018, Fall 2016, Spring 2016
Supervised independent study.

Rules & Requirements
Credit Restrictions: Enrollment is restricted; see the Introduction to Courses and Curricula section of this catalog.
Repeat rules: Course may be repeated for credit without restriction.

Hours & Format
Fall and/or spring: 15 weeks - 0 hours of independent study per week
Summer:
6 weeks - 2.5-10 hours of independent study per week
8 weeks - 1.5-7.5 hours of independent study per week
10 weeks - 1.5-6 hours of independent study per week

Additional Details
Subject/Course Level: Bioengineering/Undergraduate
Grading/Final exam status: Offered for pass/not pass grade only. Final exam not required.

Supervised Independent Study: Read More [+]