289A. Special Topics in Applied Science: Atomic, Molecular, and Optical Physics (1-5)
Lecture, laboratory, or combination. Prerequisite: graduate standing or permission of instructor. Special topic in Atomic, Molecular, and Optical Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289B. Special Topics in Applied Science: Chemical Physics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Chemical Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289C. Special Topics in Applied Science: Computational Physics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Computational Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289D. Special Topics in Applied Science: Biophotonics/Biotechnology (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Biophotonics/Biotechnology. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289E. Special Topics in Applied Science: Materials Science (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Materials Science. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289F. Special Topics in Applied Science: Imaging Science and Photonics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Imaging Science and Photonics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289G. Special Topics in Applied Science: Nonlinear Optics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Nonlinear Optics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289H. Special Topics in Applied Science: Plasma/Fusion Energy Physics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Plasma/Fusion Energy Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289I. Special Topics in Applied Science: Quantum Electronics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Quantum Electronics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289J. Special Topics in Applied Science: Condensed Matter/Statistical Physics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Condensed Matter/Statistical Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289K. Special Topics in Applied Science: Classical Optics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Classical Optics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289L. Special Topics in Applied Science: Microwave and Millimeter-Wave Technology (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Microwave and Millimeter-Wave Technology. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289M. Special Topics in Applied Science: Synchrotron Radiation Science (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Synchrotron Radiation Science. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

289N. Special Topics in Applied Science: Space Physics (1-5)
Prerequisite: graduate standing or permission of instructor. Special topic in Space Physics. May be repeated for credit up to a total of five units per segment when topic differs. — F, W, S. (F, W, S.)

290. Biophotonics Seminar (1)
Seminar — 1 hour. Prerequisite: consent of instructor. May be repeated for credit. (S/U grading only.)

290C. Graduate Research Group Conference (1)
Discussion — 1 hour. Prerequisite: consent of instructor. May be repeated for credit. (S/U grading only.)

298. Group Study (1-5)
(S/U grading only)

299. Research (1-12)
(S/U grading only)

Courses in Biophotonics (BPT)
Graduate

290. Biophotonics Seminar (1)
Seminar — 1 hour. Prerequisite: graduate standing or consent of instructor. Restricted to graduate standing. Presentation of current research in the area of biophotonics by experts in the field, followed by group discussions. May be repeated to three times for credit. (S/U grading only.)

298. Group Study (1-5)
(S/U grading only)

Engineering: Biological and Agricultural

Engineering: Biological and Agricultural

(Biological and Agricultural Engineering; Food Science and Technology)

Biological and Agricultural Engineering is the biology-based engineering discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem levels. Within this discipline, our faculty members work in a range of research areas including biotechnology engineering, agricultural and natural resources engineering, and food engineering.

The mission of the Department of Biological and Agricultural Engineering is to discover, develop, apply, and disseminate knowledge for the sustainable production, management, and use of biological materials, and to educate students for this work.

Objectives. We educate students in the fundamentals of mathematics, physical and biological sciences, and engineering, balanced with the application of principles to practical problems. We teach students to develop skills for solving engineering problems in biological systems through use of appropriate analysis, synthesis, and engineering design techniques. We prepare students for entry into engineering practice and graduate education, as well as for engagement in lifelong learning. We foster the ability of our students to collaborate and communicate effectively, and provide an awareness of the importance of economics, professional responsibility, and the environment.

Students graduating with a B.S. degree in Biological Systems Engineering from UC Davis are prepared to:

- Apply life sciences in engineering at the biochemical, cellular, organism, and ecosystem levels,
- Solve biological systems engineering problems while employed in the private or public sector,
- Consider the environmental and social consequences of their engineering activities,
- Communicate effectively with professional colleagues and public constituencies,
- Act in an ethical manner,
- Continue their education in a changing professional world.

The Biological Systems Engineering Undergraduate Program

Biological Systems Engineering is an engineering major that uses biology as its main scientific base. With rapid advances in biology and biotechnology, engineers are needed to work side by side with life sciences and to collaborate with life scientists in solving complex biological engineering problems.
scientists to bring laboratory developments into commercial production or field application. Industries in biotechnology, bioremediation, food processing, aquaculture, agriculture, plant production, animal production, and forest production all need engineers with strong training in biology. The heightened concern for environmental resources and their preservation generates many engineering opportunities as society strives to maintain balance within the biosphere.

In the freshman and sophomore years, the Biological Systems Engineering major requires sequences of courses in mathematics, physics, chemistry, engineering science, and humanities, similar to all accredited engineering programs. In addition to these core sequences, the Biological Systems Engineering major also requires courses in the biological sciences. Exclusive of General Education units, the Biological Systems Engineering major requires a minimum of 161 units (90 units in the lower division; 71 units in the upper division).

Biological Systems Engineering graduates take jobs in the biotechnology, energy, food, and medical industries; work for state and federal agencies; or pursue graduate work. Students also can use the program as a pathway to professional schools in medicine, veterinary medicine, dentistry, or business. The Biological Systems Engineering program is accredited by the Engineering Accreditation Commission of ABET; see http://www.abet.org.

Students are encouraged to adhere carefully to all prerequisite requirements. The instructor is authorized to drop students from a course for which stated prerequisites have not been completed.

### Lower Division Required Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Mathematics 21A 21B 21C 21D</td>
<td>............</td>
<td>16</td>
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<tr>
<td>Mathematics 22A 22B</td>
<td>............</td>
<td>6</td>
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<tr>
<td>Physics 9A 9B 9C</td>
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<td>15</td>
</tr>
<tr>
<td>Chemistry 2A 2B</td>
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<td>10</td>
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<tr>
<td>Chemistry 8A or 118A</td>
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<td>2 or 4</td>
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<tr>
<td>Chemistry 8B or 118B</td>
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</tr>
<tr>
<td>Biological Sciences 2A 2B 2C</td>
<td>..........</td>
<td>15</td>
</tr>
<tr>
<td>Engineering 6 35 17</td>
<td>..........</td>
<td>15</td>
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<tr>
<td>Biological Systems Engineering 1</td>
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<td>4</td>
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<tr>
<td>Biological Systems Engineering 75</td>
<td>..........</td>
<td>5</td>
</tr>
<tr>
<td>University Writing Program 1 1Y or 1V</td>
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### Upper Division Requirements:

If your career objective is a professional degree in the health sciences (e.g., medicine, veterinary medicine, or dentistry), you should consult with advisors from the appropriate school to plan for successful admission and to ensure that you take specific courses that may be required and that you have the necessary experience. The upper division requirements are listed following the areas of specialization:

- Biotechnology Engineering
- Agricultural and Natural Resources Engineering
- Food Engineering

### Areas of Specialization

#### Biotechnology Engineering

Biotechnology involves the handling and manipulation of living organisms or their components to produce useful products. Students specializing in biotechnology engineers integrate and apply knowledge from biology, chemical engineering, and physiology to applied biology to solve problems in renewable energy production, large-scale biotechnical production, control of biological systems, and bio-based materials production. Students may focus on the mechanisms and processes for the sustainable production and use of energy from renewable biological sources. Students may also focus on the challenges in scale-up laboratory developments to industrial production, including production, packaging, and application of biocontrol agents for plant pests and diseases; genetically altered plants; plant materials and food products; and microbial production of biological products, tissue culture, and bioremediation. Students may also focus on the development of biosensors to detect microorganisms and specific substances, useful in the development of products based on biological processes and materials.

Biotechnical engineers work in the biotech industries on process design and operation, scale-up, and instrumentation and automation.

### Recommended biological science electives:

- **Biological Sciences 101, 102, 103**
- **Microbiology 102**
- **Molecular and Cellular Biology 120L**
- **Plant Biology 113**

### Recommended engineering electives:

- **Biological Systems Engineering 161**
- **Chemical Engineering 161B 161C 161L**
- **Civil and Environmental Engineering 143, 148A, 149, 150, 153**
- **Engineering 180**
- **Mechanical Engineering 161, 162, 163**


#### Agricultural and Natural Resources Engineering

With the world population expected to grow over the next several decades, major concerns lie with meeting the world's need for agricultural and with the sustainable use of limited natural resources. Students specializing in agricultural and natural resources engineering combine analysis and design with applied biology to solve problems in producing, transporting, and processing biological products leading to food, fiber, energy, pharmaceuticals, and other human needs.

Students may focus on automation and control of field operations and engineered systems, robotics, and on the biomechanics of humans and animals. They may also focus on engineering issues related to the sustainable use of natural resources, particularly energy and water, but also land and air. Agricultural and natural resources engineers design machinery, processes, and systems for productive plant and animal culture, while improving overall sustainability.

Agricultural and natural resources engineers are employed as practicing professionals and managers with agricultural producers, equipment manufacturers, irrigation districts, food processors, consulting engineering firms, startup companies, and government agencies. Graduates with interest in biomechanics work in industry on the design, evaluation, and application of human-centered devices and systems, as well as on improving worker health and safety.

### Recommended biological science electives:

- **Animal Emphasis**
  - **Avian Sciences 100**
  - **Animal Science 143, 144, 146**
  - **Neurobiology, Physiology, and Behavior 101**
  - **Soil Science 100**
- **Aquaculture Emphasis**
  - **Animal Science 118, 131, 136A**
  - **Applied Biological Systems Technology 163**
  - **Wildlife, Fish, and Conservation Biology 120, 121**
- **Biomechanics Emphasis**
  - **Biological Sciences 102**
  - **Neurobiology, Physiology and Behavior 101**
  - **Exercise Biology 103**
  - **Cell Biology and Human Anatomy 101**
  - **Plant Emphasis**
  - **Entomology 100**
  - **Environmental Horticulture 102**
  - **Environmental, Food, and Resource Policy 100**
  - **Environmental Toxicology 101**
  - **Hydrologic Sciences 124**
  - **Microbiology 125**
  - **Pest and Disease 111**

### Soil Science 100

**Recommended engineering electives:**

- **Biological Systems Engineering 128, 145**
- **Biomedical Engineering 152, 153**
- **Civil and Environmental Engineering 140, 141, 142, 144, 145, 148A, 171**
- **Engineering 111, 121, 180**

**Additional recommended electives:**

- **Applied Biological Systems Technology 150, 161, 165**


**Food Engineering.** Producing the food we eat every day constitutes the largest industrial sector of the U.S. economy, and this production involves the work of engineers in a wide variety of food industries, both at home and around the world. Students specializing in food engineering design food processes and operate equipment and facilities for production of high quality, safe, and nutritious food with minimal impact of these operations on the environment.

Students learn to apply engineering principles and concepts to handle, store, process, package, and distribute food and related products. In addition to engineering principles, the food engineering specialization provides an understanding of the chemical, biochemical, microbiological, and physical characteristics of food. Students study concepts of food refrigeration, freezing, thermal processing, drying, and other food operations, food digestion, and health and nutrition in food system design.

**Food engineers work as practicing engineers, scientists, and managers in the food industry.**

### Recommended biological science electives:

- **Biological Sciences 101, 102, 103**
- **Environmental Science and Policy 110**
- **Environmental Toxicology 101**
- **Food Science and Technology 104, 104L, 119, 128**
- **Plant Sciences 172**

### Recommended engineering electives:

- **Biological Systems Engineering 161**
- **Chemical Engineering 157**
- **Mechanical Engineering 171, 172**

**Suggested Advisers.** G. Bornhorst, J. de Moura Bell, J. Jeoh, M. McCarthy, N. Nitin, Z. Pan, D. Slaughter

### Upper Division Required Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
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<tbody>
<tr>
<td>Engineering 100, 102, 104, 105, 106</td>
<td>............</td>
<td>18</td>
</tr>
<tr>
<td>Biological Systems Engineering 103, 125, 127, 130, 165, 170A, 170B, 170C, 170CL</td>
<td>............</td>
<td>29</td>
</tr>
<tr>
<td>Biological Systems Engineering—Select a minimum of 4 units from all upper division Biological Systems Engineering courses not otherwise required, with the exception of Biological Systems Engineering courses 189-199</td>
<td>............</td>
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<tr>
<td>Statistics 100</td>
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<tr>
<td>Engineering electives—Select a minimum of three units.</td>
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<td>3</td>
</tr>
<tr>
<td>Civil and Environmental Engineering 123, Computer Science Engineering 188, Engineering 103, 160, all courses numbered 190-197 and 199 (except Engineering 190, which may be taken for 2 units of engineering elective credit)</td>
<td>............</td>
<td>3</td>
</tr>
<tr>
<td>Biological science electives—All upper-division courses in the College of Biological Sciences (with the exception of Biological Sciences 132, Evolution and Ecology 175, 268, Fall 2011 and Revised General Education (GE) Categories: AH—Arts and Humanities; SE—Science and Engineering; SS—Social Sciences; AGCM—American Cultures DD—Domestic Diversity; DL—Global Skills; DLQ—Quantitative; SL—Scientific; VL—Visual; WC—World Cultures; WE—Writing Experience Pre-Fall 2011 General Education (GE) Categories: Arth—Arts and Humanities; SciEng—Science and Engineering; SocSci—Social Sciences; Div—Domestic Diversity; Wrt—Writing Experience Quarter Offered: Fe-Fall, W—Winter, S—Spring, Su—Summer; 2017/2018 offering in parentheses</td>
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</tbody>
</table>
Exercise Biology 102, 112, 115, 118 through 149L, Microbiology 100 and all courses numbered 190-199 may be used as biological science electives. The following courses may also be taken as biological science electives: Applied Biological Technology 161; Animal Science 118, 143, 144, 146; Agricultural Management and Rangeland Resources 110A; Atmospheric Science 133; Avian Sciences 100; Cell Biology and Human Anatomy 101, 101I; Entomology 100; Environmental Horticulture 102; Environmental Science Policy and Management 120, 182, 185 (offered at UC Berkeley); Environmental Science and Policy 100, 110, 155; Environmental Toxicology 101, 112A, 131; Food Science and Technology 102A, 104L, 119, 120, 121, 128, 159; Infectious Diseases 141I; Soil Science 100; Wildlife, Fish, and Conservation Biology 121. Students may choose other upper division courses with substantial biological content offered by the College of Agricultural and Environmental Sciences; consultation with a faculty adviser and approval by petition is required. ... 3 Upper Division Composition Requirement* one course from the following: University Writing Program 101, 102B, 102F, 102G, 102H, 104, 104F, 104T (grade of C- or better is required) ... 4 *The Upper-Division composition exam administered by the College of Letters and Sciences cannot be used to satisfy the upper-division composition requirement for students in the Biotechnological Systems Engineering program.

Master Undergraduate Adviser. T. J. Joh

Energy Minor Programs
There is an urgent need to develop and commercialize technologies for the sustainable conversion and use of energy. The goal of these minors is to prepare students for careers that require training in energy science and technology, efficiency, and policy. Clean technologies and green technologies including energy are some of the fastest growing markets for new investments. Well trained individuals in all related fields are needed to provide the level of expertise required to advance technology and policy and to satisfy national and global objectives for greater energy sustainability. The minors are designed to accommodate persons of diverse backgrounds with educational interests in areas that may include engineering, science, policy, economics, planning, and management.

Energy Science and Technology Minor
All courses must be taken for a letter grade. A grade of C- or better is required for all courses used to satisfy minor requirements with an overall GPA in the required minor courses of 2.00 or better.

Minor Requirements:

Energy Policy Minor
All courses must be taken for a letter grade. A grade of C- or better is required for all courses used to satisfy the minor requirements with an overall GPA in the required minor courses of 2.00 or better.

Minor Requirements:

Energy Efficiency Minor
All courses must be taken for a letter grade. A grade of C- or better is required for all courses used to satisfy the minor requirements with an overall GPA in the required minor courses of 2.00 or better.

Minor Requirements:

Courses in Engineering: Biological Systems (EBS)

Lower Division
1. Foundations of Biological Systems Engineering (4)
Lecture—2 hours, laboratory—3 hours; project—3 hours. Restricted to students in Biological Systems Engineering. Introduction to engineering and the engineering design process with examples drawn from the field of biological systems engineering. Introduction to computer-aided design and mechanical fabrication of designs. Students work on a quarterly design project. GE credit: SciEng 10L, OL, SE, SL, VH. F. (F.) Barnhart, Fathallah, Jenkins

75. Properties of Materials in Biological Systems (4)
Lecture—3 hours, laboratory—3 hours. Prerequisite: Biological Sciences 2A; Physics 9C (may be taken concurrently). Properties of typical biological materials; composition and structure with emphasis on the effects of physical and biochemical properties on design of engineered systems; interactions of biological materials with typical engineering materials. GE credit: SciEng 10L, OL, SE, SL, VI, WE. W. (W.) Slaughter, Zicari

90C. Research Group Conference in Biological Systems Engineering (1)
Discussion—1 hour. Prerequisite: lower division standing in Biological Systems Engineering or Food Engineering; consent of instructor. Research group conference. May be repeated for credit. (P/NP grading only) GE credit: SE. F, W, S. F, W, S.

92. Internship in Biological Systems Engineering (1-5)
Internship. Prerequisite: lower division standing; project approval prior to period of internship. Supervised work experience in biological systems engineering. May be repeated for credit. (P/NP grading only) GE credit: SE.
Upper Division
cles with wheels or tracks. Operating principles of field machines and basic mechanisms used in their design. GE credit: SciEng|QI, SE, VI, WE.—S. (JS) Hartough
120. Power Systems Design (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 17, 102, 103, 105. Design and perform-
one of power devices and systems including con-
bustion engines, generators and motors, fluid power systems, fuels, and emerging technologies. Selection of units for power matching and optimum performance. GE credit: SciEng|QI, SE, SL, VI, WE.—F, W (FJ) 125. Heat Transfer in Biological Systems (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: course 103; Engineering 105; Biological Sciences 2A, 2B and 2C. Fundamentals of heat transfer with application to biological systems. Steady and trans-
127. Mass Transfer and Kinetics in Biological Systems (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: course 123. Fundamentals of mass transfer and kinetics in biological systems. Molecular diffusion and convection. Thermodynamics and biochemical kinetics. Chemical and physical rate equations. Hetero-
128. Biomechanics and Ergonomics (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: Statistics 100, Engineering 102. Limited enrollment. Anatomical, physiological, and biomechanical bases of human performance. Human motor capa-
cibilities, body mechanics, kinematics and anthropom-
130. Modelling and Dynamic Processes in Biological Systems (4) Lecture—3 hours; discussion—1 hour. Prerequisite: course 75; Engineering 6 or Computer Science & Engineering 30; grade of C or better in Mathemat-
ics 22B with consent eligibility. Techniques for modeling processes through mass and energy balance, rate equations, and equations of state. Computer problem solution of models. Example models include evaporation, respi-
ration heating, thermal processing of foods, and plant growth. GE credit: SciEng|QI, QL, SE, SL, VI, WE.—W, W (WM) Fan, Upadhayya
135. Bioenvironmental Engineering (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: courses 125, 130. Biological responses to environ-
mental conditions. Principles and engineering design of environmental control systems. Overview of envi-
ronmental pollution problems and legal restrictions for biological systems. Introduction of environmental quality assessment techniques and environmental pollution control technologies. GE credit: SciEng|QI, SE, SL, VI, WE.—F, W (FJ) Zhang
144. Groundwater Hydrology (4) Lecture—4 hours. Prerequisite: Mathematics 168 or 21A, Hydrologic Science 103N. GE credit: SciEng|QI, SE, SL, VI, VL.—F (F) Fogg, Harter
145. Irrigation and Drainage Systems (4) Lecture—4 hours. Prerequisite: course 103 or Hydro-
logic Science 103N. Engineering and scientific prin-
ciples applied to surface and subsurface irrigation and micro irrigation systems and drainage systems within economic, biological, and environmental con-
straints. Interaction between irrigation and drainage. GE credit: SciEng|QI, SE, SL, VL.—W (WJ) Gris-
mer, Wallender
147. Runoff, Erosion and Water Quality Management in the Tahoe Basin (3) Lecture/laboratory—30 hours; fieldwork—15 hours; discussion—10 hours. Prerequisite: Physics 78B or 98, Mathematics 16C or 21C, Civil and Environmental Hydrology 142 or Hydrologic Science 141 or Environmental and Resource Sci-
ences 100. Practice of hydrology and runoff water quality management from Tahoe Basin slopes. Devel-
opment of hillside and riparian restoration con-
cepts, modeling and applications from physical science perspectives including precipitation-runoff relationships, sediment transport, and detention ponds. Five days of instruction in Tahoe City. (Same course as Hydrologic Science 147.) GE credit: SciEng|QI, SE, SL, VL.—W (WJ) Mc.
Carthy
161. Kinetics and Bioreactor Design (4) Lecture—3 hours; discussion—1 hour. Prerequisite: course 127. Provide the basic principles of reactor design for bioprocess applications. This course emphasizes the following topics. 1) kinetics and reactor engineering principles; 2) bio-reaction kinetics; and 3) bioreactor design. GE credit: SciEng|QI, SE, SL, VL.—W (WJ) Jeon
165. Biostatistics and Control (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100. Instrumentation and control for biological production systems. Measurement system concepts, instrumentation and transducers for sens-
ing physical and chemical parameters, data acqui-
170A. Engineering Design and Professional Responsibilities (3) Lecture—2 hours; laboratory—3 hours. Prerequisite: course 1, Engineering 102, 104. Engineering design including professional responsibilities. Emphasis on project selection, data sources, specifi-
cations, human factors, biological materials, safety ac-
duities, and professionalism. Detailed design pro-
possals will be developed for courses 170B and 170BL. GE credit: SciEng|QI, QL, SE, SL, VL, WE.—F (FJ) Giles, Zhang
170B. Engineering Projects: Design (2) Discussion—2 hours. Prerequisite: course 170A; course 170BL required concurrently. Individual or group projects involving the design of devices, struc-
tures, or systems to solve specific engineering prob-
lems in biological systems. Project for study is jointly selected by student and instructor. GE credit: SciEng|QI, QL, SE, SL, VI, WE.—W (WM) Giles, Zhang
170BL. Engineering Projects: Design Laboratory (1) Laboratory—2 hours. Prerequisite: course 170B required concurrently. Individual or group projects involving the design of devices, structures, or systems to solve specific engineering problems in biological systems. GE credit: SciEng|OL, QI, SE, SL, VI, WE.—W (W)
220. Pilot Plant Operations in Aquacultural Engineering (3) Lecture—2 hours; laboratory—6 hours. Prerequisite: Civil Engineering 243A.423B or Applied Biological Systems Technology 161, 163. Topics in water treatment as they apply to aquaculture operations. Laboratory study of operations at aquaculture. Offered in alternate years. —(F) Hung

228. Occupational Musculoskeletal Disorders (3) Lecture—2 hours; laboratory—3 hours. Prerequisite: graduate standing and consent of instructor. Epilep- tology and etiology of occupational musculoskeletal disorders (MSDs) with focus on low back and upper extremities disorders; anatomical and biome- chanical function of back and upper extremities; MSDS risk factors assessment and control; research opportunities related to MSDS. —S. (S.) Fathallah

231. Mass Transfer in Food and Biological Systems (3) Lecture/discussion—3 hours. Prerequisite: graduate standing. Application of mass transfer principles to food and biological systems. Study of mass transfer affecting food quality and shelf life. Analysis of mass transfer in polymer films used for coating and pack- aging foods and controlling release of biologically active compounds. Offered in alternate years. —(W)

233. Analysis of Processing Operations: Drying and Particulate Processes (3) Lecture—3 hours. Prerequisite: course in food or pro- cess engineering, familiarity with FORTRAN. Diffu- sion theory in drying of solids. Analysis of fixed-bed and continuous-flow dryers. Steady-state and dynamic modeling of the evaporators: multiple effects, mechanical and thermal recom- pression, control systems. Offered in alternate years. —(W)

235. Advanced Analysis of Unit Operations in Food and Biological Engineering (3) Lecture—3 hours. Prerequisite: course 132. Analysis and design of food processing operations. Steady state and dynamic heat and mass transfer models for operations involving phase change such as freezing and drying. Separation processes including mem- brane applications in food and fermentation sys- tems. —(S)

237. Thermal Process Design (3) Lecture—2 hours; discussion—1 hour. Prerequisite: course in heat transfer. Heat transfer and biological basis for design of heat sterilization of foods and other biological materials in containers or in bulk. Offered in alternate years. —F. M. McCarthy

240. Infiltration and Drainage (3) Lecture—3 hours. Prerequisite: Soil Science 107, Engineering 103. Aspects of multi-phase flow in soils and their application to infiltration and immiscible displacement problems. Gas phase transport and entrainment during infiltration, and oil-water-gas dis- placement will be considered. Offered in alternate years. —W. Grismer

241. Sprinkle and Trickle Irrigation Systems (3) Lecture—2 hours; laboratory—3 hours. Prerequisite: course 145/Hydrologic Science 115. Computerized design of sprinkle and trickle irrigation systems. Con- sideration of distribution functions and water yield functions. Offered in alternate years. —S

242. Hydraulics of Surface Irrigation (3) Lecture—3 hours. Prerequisite: course 145, Hydro- logic Science 115. Mathematical models of surface- irrigation systems for prediction of the ultimate dispo- sition of water flowing onto a field. Quantity of run- off and distribution of infiltrated water over field length as a function of soil hydrologic characteristics and inflow rates. Offered in alternate years. —(S)

243. Water Resource Planning and Management (3) Lecture—3 hours. Prerequisite: Hydrologic Science 141.1 or the equivalent. Applications of deterministic and stochastic mathematical programming tech- niques to water resource planning, analysis, design, and management. Water allocation, capacity expansion, and reservoir optimization including use of surface water and groundwater. Water quality management. Irrigation planning and operation models. (Same course as Hydrologic Science 243.) Offered in alternate years. —(F)

245. Waste Management for Biological Production Systems (3) Lecture—3 hours. Prerequisite: graduate standing or consent of instructor. Characterization of solid and liquid residues from animal and food produc- tion systems. Study of methods and system design for handling, treatment, and disposal/utilization of these materials. —W. (W) Zhang

260. Analog Instrumentation (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100. Instrument characteristics; general- ized instrument models, calibration, and frequency response. Signal conditioning: operational amplifier circuits, filtering, and noise. Transducers: motion, force, pressure, flow, temperature, and photoelec- tric. Offered in alternate years. —W.

262. Computer Interfacing and Control (4) Lecture—3 hours; laboratory—3 hours. Prerequisite: Engineering 100. Programming in C++ and object-oriented programming in C++. Analog and digital signal conversion, data acquisition and com- puter control. Offered in alternate years. —(S) Del- wiche

265. Design and Analysis of Engineering Experiments (5) Lecture—3 hours; lecture/discussion—2 hours. Prerequisite: Statistics 100. Agricultural Systems and Environment 120, or an introductory course in statis- tics. Simple linear, multiple, and polynomial regressions, correlation, residuals, model selection, one- way ANOVA, fixed and random effect models, sam- ple size, multiple comparisons, randomized block, repeated measures, and Latin square designs, facto- rial experiments, nested design and subsampling, split-plot design, statistical software packages. —S. (S.) Slaughter, Upadhyaya

267. Renewable Bioprocessing (3) Lecture—3 hours. Prerequisite: course 160, Biologi- cal Sciences 101 or Microbiology 102. Applica- tions of biotechnology and bioprocess engineering toward the use of agricultural and renewable feed- stocks for the production of biochemicals. Design and modeling of microbial- and plant-based produc- tion systems including associated fermentation, extraction, and purification processes. Offered in alternate years. —F. VanderGheynst

268. Polysaccharides Surface Interactions (3) Lecture—3 hours. Prerequisite: graduate students in science or engineering. Study of polysacchar- ides science theories as applied to physical and chemical interactions of carbohydrates and polysac- charides. Offered in alternate years. —F. Jeoh

270. Modeling and Analysis of Biological and Physical Systems (3) Lecture—3 hours. Prerequisite: familiarity with a pro- gramming language. Mathematical modeling of bio- logical systems: model development; analytical and numerical solutions. Case study of biological and physical spec- ializations within biological and agricultural engi- neering. Offered in alternate years. —S. Upadhyaya

275. Physical Properties of Biological Materials (3) Lecture—2 hours; laboratory—2 hours. Prerequisite: consent of instructor. Selected topics on physical properties, such as mechanical, optical, rheological,
Engineering: Biomedical

and aerodynamic properties, as related to the
design of harvesting, handling, sorting, and process-
ing equipment. Techniques for measuring and
recording physical properties of biological materi-
als. Offered in alternate years. —S. M. McCarthy,
Nitin
289A. Selected Topics in Biological Systems
Engineering; Animal Systems Engineering
(1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Animal Systems Engineering. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289B. Selected Topics in Biological Systems
Engineering; Aquacultural Engineering
(1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Aquacultural Engineering. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289C. Selected Topics in Biological Systems
Engineering; Forest and Wood Products
(1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Forest and Wood Products. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289D. Selected Topics in Biological Systems
Engineering; Energy Systems (1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Energy Systems. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289E. Selected Topics in Biological Systems
Engineering; Environmental Quality (1-5)
Variable—1-3 hours. Prerequisite: consent of in-
structor. Special topics in Environmental Quality. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289F. Selected Topics in Biological Systems
Engineering; Food Engineering (1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Food Engineering. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289G. Selected Topics in Biological Systems
Engineering; Irrigation and Drainage (1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Irrigation and Drainage. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289H. Selected Topics in Biological Systems
Engineering; Plant Production and Harvest
(1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Plant Production and Harvest. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289J. Selected Topics in Biological Systems
Engineering; Postharvest Engineering (1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Postharvest Engineering. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
289K. Selected Topics in Biological Systems
Engineering; Sensors and Actuators (1-5)
Variable—1-5 hours. Prerequisite: consent of in-
structor. Special topics in Sensors and Actuators. May be
repeated for credit when topic differs. —F, W, S. (F, W, S.)
290. Seminar (1)
Seminar—1 hour. Prerequisite: graduate standing.
Weekly seminars on recent advances and selected
topics in biological systems engineering. Course
theme will change from quarter to quarter. May be
repeated for credit. (S/U grading only.)
290C. Graduate Research Conference (1)
Discussion—1 hour. Prerequisite: consent of in-
structor. Research problems, progress and techniques in biological systems engineering. May be
repeated for credit. (S/U grading only.)—F, W, S. (F, W, S.)
298. Group Study (1-5)
299. Research (1-12)
300. Graduation Research Conference (1)
Discussion—1 hour. Prerequisite: consent of in-
structor. Research problems, progress and techniques in biological systems engineering. May be
repeated for credit. (S/U grading only.)—F, W, S. (F, W, S.)
Professional
390. Supervised Teaching in Biological and
Agricultural Engineering (1-3)
Laboratory—3 hours; tutorial—9 hours. Prerequi-
tes: graduate standing; consent of instructor. Tutor-
ing and teaching students in undergraduate courses offered in the Department of Biological and
Agricultural Engineering. Weekly conferences with in-
structor; evaluation of teaching. Preparing for and
conducting demonstrations, laboratories and discus-
sions. Preparing and grading exams. May be
repeated for a total of 6 units. (S/U grading only.)—
F, W, S. (F, W, S.)

Engineering: Biomedical

(College of Engineering)

Alyssa Panitch, Chairperson of the Department
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2303 Genome and Biomi-
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Vivek J. Srinivasan, Ph.D., Associate Professor
(Biomedical Engineering; Medicine: Ophthalmology)
Julie L. Sutcliffe, Ph.D., Associate Professor
(Physical Imaging and Medical Biology)
Maury Hull, Ph.D., Professor Emeritus (Biomedical
Engineering; Mechanical and Aerospace
Engineering)

The Biomedical Engineering Undergraduate Major

The Biomedical Engineering program is accredited
by the Engineering Accreditation Commission of
ABET, see http://www.abet.org.

Biomedical engineering is an interdisciplinary area
of study that integrates knowledge from engineering
with the biomedical sciences. It is a very diverse
field, with biomedical engineers working in systems
ranging from medical imaging to the design of artifi-
cial organs. Some major research advances in bio-
medical engineering include the left ventricular assist
device (LVAD), artificial joints, kidney dialysis, bioen-
gineered skin, angioplasty, computed tomography
(CT), and flexible endoscopes. Students who choose
biomedical engineering are interested in being
of service to human health but do not routinely interact
directly with patients.

The mission of the BS degree program of the Depart-
ment of Biomedical Engineering is to combine
exceptional teaching with state-of-the-art research
for the advancement of technologies and computational
techniques that meet medical and societal chal-

lenges. As a biomedical engineer, you can choose
employment opportunities in industry, hospitals, aca-

demic research institutes, teaching, national labora-
tories, or government regulatory agencies.

The educational objectives of our program are that
we graduate successful careers related to
biomedical engineering or another area of the stu-
dents’ choosing, through employment in industry
or government, or through pursuit of graduate or pro-
fessional degrees; and contribute effectively to soci-
ety through engineering practice, research and
development, education, or in governmental, regula-
tory or legal aspects.

The biomedical engineering curriculum has been
designed to provide a solid foundation in mathemat-
ics, life and physical sciences, and engineering, and
to provide sufficient flexibility in the upper division
requirements to encourage students to explore spe-
cializations within the field. Our instructional pro-
gram is designed to impart knowledge of
contemporary issues at the forefront of biomedical
engineering research. Exclusive of General Educa-
tion units, the minimum number of units required for
the Biomedical Engineering degree is 157.

For information about graduate degree options, see
Biomedical Engineering (A Graduate Group), on
page 194.

Lower Division Required Courses

Students are encouraged to adhere carefully to all
prerequisite requirements. The instructor is author-
ized to drop students from a course for which stated
prerequisites have not been completed.

UNITS

Mathematics 21A or 21AH; 21B or 21BH;
21C or 21CH; 21D .................. 16
Mathematics 22A or 22B ................. 6
Physics 9A or 9HA; 9B, 9C ........... 15
Chemistry 2A or 2AH; 2B or 2BH; 2C or
2CH ................................ 15

Fall 2011 and on Revised General Education (GE): AH—Arts and Humanities; SE—Science and Engineering; SS—Social Sciences,
AGCH=American Cultures, DD=Biocommunity Diversity, OL=Oral Skills, QL=Quantitative, SL=Scientific, VL=Visual, WC=World Cultures, WE=Writing Experience
Pre-Fall 2011 General Education (GE): ArtHum=Arts and Humanities; SciEng=Science and Engineering; SocSci=Social Sciences; Div=Domestic Diversity; Writ=Writing Experience
Quarter Offered: F=fall, W=Winter, S=Spring, Su=Summer; 2017-2018 offering in parentheses