Department of Chemical Engineering and Materials Science

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916 Engineering Tower
949-824-5802
http://www.eng.uci.edu/dept/chems

Overview
The Department of Chemical Engineering and Materials Science offers the B.S. in Chemical Engineering, the B.S. in Materials Science Engineering, the M.S. and Ph.D. in Chemical and Biochemical Engineering, and the M.S. and Ph.D. in Materials Science and Engineering.

On This Page:
- Chemical Engineering
- Materials Science Engineering

Undergraduate Major in Chemical Engineering

Program Educational Objectives: Graduates of the Chemical Engineering program will (1) demonstrate achievement by applying a broad knowledge of chemical engineering; (2) apply critical reasoning and quantitative skills to identify and solve problems in chemical engineering; (3) implement skills for effective communication and teamwork; (4) demonstrate the potential to effectively lead chemical engineering projects in industry, government, or academia; and (5) exhibit a commitment to lifelong learning.

(Program educational objectives are those aspects of engineering that help shape the curriculum; achievement of these objectives is a shared responsibility between the student and UCI.)

Chemical Engineering uses knowledge of chemistry, mathematics, physics, biology, and humanities to solve societal problems in areas such as energy, health, the environment, food, clothing, shelter, and materials and serves a variety of processing industries whose vast array of products include chemicals, petroleum products, plastics, pharmaceuticals, foods, textiles, fuels, consumer products, and electronic and cryogenic materials. Chemical engineers also serve society in improving the environment by reducing and eliminating pollution.

The undergraduate curriculum in Chemical Engineering builds on basic courses in chemical engineering, other branches of engineering, and electives which provide a strong background in humanities and human behavior. Elective programs developed by the student with a faculty advisor may include such areas as applied chemistry, biochemical engineering, chemical reaction engineering, chemical processing, environmental engineering, materials science, process control systems engineering, and biomedical engineering.

Admissions

High School Students: See School Admissions information.

Transfer Students: Preference will be given to junior-level applicants with the highest grades overall, and who have satisfactorily completed the following required courses: one year of approved calculus, one year of calculus-based physics with laboratories (mechanics, electricity and magnetism), completion of lower-division writing, one year of general chemistry (with laboratory), and one additional approved course for the major.

Students are encouraged to complete as many of the lower-division degree requirements as possible prior to transfer. Students who enroll at UCI in need of completing lower-division coursework may find that it will take longer than two years to complete their degrees. For further information, contact The Henry Samueli School of Engineering at 949-824-4334.

Requirements for the B.S. in Chemical Engineering

All students are required to meet the University Requirements.

All students are required to meet the School Requirements.

Major Requirements

Mathematics and Basic Science Courses:

| CHEM 1A- 1B- 1C- 1LC- 1LD | General Chemistry and General Chemistry Laboratory
<table>
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<tbody>
<tr>
<td></td>
<td>General Chemistry and General Chemistry Laboratory</td>
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<td></td>
<td>General Chemistry and General Chemistry Laboratory</td>
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</tbody>
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1
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 51A-51B-51C-51LB-51LC</td>
<td>Organic Chemistry and Organic Chemistry and Organic Chemistry and Organic Chemistry Laboratory and Organic Chemistry Laboratory</td>
</tr>
<tr>
<td>or</td>
<td>CHEM H52A-H52B-H52C-H52LA-H52LB</td>
</tr>
<tr>
<td>CHEM 132B-132C</td>
<td>Quantum Principles, Spectroscopy, and Bonding and Molecular Structure and Elementary Statistical Mechanics</td>
</tr>
<tr>
<td>MATH 2A-2B</td>
<td>Single-Variable Calculus and Single-Variable Calculus</td>
</tr>
<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
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<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
</tr>
<tr>
<td>PHYSICS 7C-7LC</td>
<td>Classical Physics and Classical Physics Laboratory</td>
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<tr>
<td>PHYSICS 7D-7LD</td>
<td>Classical Physics and Classical Physics Laboratory</td>
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</table>

**Engineering Topics Courses:**

Students must complete a minimum of 18 units of engineering design.

- CBEMS 45A-45B-45C: Chemical Processing and Materials Balances and Chemical Processing and Energy Balances and Chemical Engineering Thermodynamics
- CBEMS 110: Reaction Kinetics and Reactor Design
- CBEMS 125A-125B-125C: Momentum Transfer and Heat Transfer and Mass Transfer
- CBEMS 128: Introduction to Numerical Methods in Engineering
- CBEMS 130: Separation Processes
- CBEMS 135: Chemical Process Control
- CBEMS 140A-140B: Chemical Engineering Laboratory I and Chemical Engineering Laboratory II
- CBEMS 149A-149B: Chemical Engineering Design I and Chemical Engineering Design II
- ENGR 54: Principles of Materials Science and Engineering
- ENGRMAE 10: Introduction to Engineering Computations
- or EECS 10: Computational Methods in Electrical and Computer Engineering

Students select, with the approval of a faculty advisor, any additional engineering topics courses needed to satisfy school and department requirements.

**Technical Elective Courses:**

Students select, with the approval of a faculty advisor, a minimum of 19 units of technical electives. Students may select an area of specialization and complete the associated requirements, as shown below.

(The nominal Chemical Engineering program will require 192 units of courses to satisfy all university and major requirements. Students typically need at least 17 units of engineering topics from technical electives to meet school requirements. Because each student comes to UCI with a different level of preparation, the actual number of units will vary.)

**Engineering Professional Topics Course:**

ENGR 190W: Communications in the Professional World

**Specialization in Biomolecular Engineering:**

Requires:
- CBEMS 112: Introduction to Biochemical Engineering

and a minimum of 8 units from the following:
### Specialization in Energy and the Environment:
Requires a minimum of 11 units including at least one course from the following:

- CBEMS 133 Nuclear and Radiochemistry
- CBEMS 141 Nano-Scale Materials and Applications
- CBEMS 143 Chemistry and Technology for the Nuclear Fuel Cycle
- CBEMS 199 Individual Study (up to 4 units; or CBEMS H199, up to 4 units)
- ENGRCEE 160 Environmental Processes

and select the remaining units from the following:

- ENGRCEE 162 Introduction to Environmental Chemistry
- ENGRCEE 163 Wastewater Treatment Process Design
- ENGRCEE 171 Water Resources Engineering
- ENGRCEE 172 Groundwater Hydrology
- ENGRMAE 110 Combustion and Fuel Cell Systems
- ENGRMAE 115 Applied Engineering Thermodynamics
- ENGRMAE 164 Air Pollution and Control

### Specialization in Materials Science:
Requires a minimum of 12 units from:

- CBEMS 154 Polymer Science and Engineering
- CBEMS 155 Mechanical Behavior and Design Principles
- CBEMS 158 Ceramic Materials
- CBEMS 163 Computer Techniques in Experimental Research
- CBEMS 174 Semiconductor Device Packaging
- CBEMS 175 Design Failure Investigation
- CBEMS 199 Individual Study (up to 4 units; or CBEMS H199, up to 4 units)
- ENGR 150 Mechanics of Structures
- ENGRMAE 155 Composite Materials and Structures

1 Requires ENGR 30, not included in total.

### Planning a Program of Study
The sample program of study chart shown is typical for the major in Chemical Engineering. Students should keep in mind that this program is based upon a sequence of prerequisites, beginning with adequate preparation in high school mathematics, physics, and chemistry. Students who are not adequately prepared, or who wish to make changes in the sequence for other reasons, must have their program approved by their faculty advisor. Chemical Engineering majors must consult at least once every year with the academic counselors in the Student Affairs Office and with their faculty advisors.

### Sample Program of Study — Chemical Engineering

#### Freshman

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<thead>
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<tbody>
<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
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<tr>
<td>EECS 10 or ENGRMAE 10</td>
<td>PHYSICS 7C</td>
<td>PHYSICS 7D</td>
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<td>CHEM 1A</td>
<td>PHYSICS 7LC</td>
<td>PHYSICS 7LD</td>
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<td>General Education</td>
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<td>CHEM 1C</td>
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<td>General Education</td>
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<td>CHEM 1LC</td>
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</table>
Undergraduate Major in Materials Science Engineering

Program Educational Objectives: Graduates of the Materials Science Engineering program will (1) establish a productive Materials Science and Engineering career in industry, government or academia; (2) apply critical reasoning and the requisite analytical/quantitative skills in seeking solutions to materials science and engineering problems; (3) promote innovation in materials development and design through effective leadership, skilled communications, and multidisciplinary teamwork; (4) exhibit a commitment to engineering ethics, environmental stewardship, continued learning, and professional development.

(Program educational objectives are those aspects of engineering that help shape the curriculum; achievement of these objectives is a shared responsibility between the student and UCI.)

Since the beginning of history, materials have played a crucial role in the growth, prosperity, security, and quality of human life. In fact, materials have been so intimately related to the emergence of human culture and civilization that anthropologists and historians have identified early cultures by the name of the significant materials dominating those cultures. These include the stone, bronze, and iron ages of the past. At the present time, the scope of materials science and engineering has become very diverse; it is no longer confined to topics related to metals and alloys but includes those relevant to ceramics, composites, polymers, biomaterials, nanostructures, intelligent materials, and electronic devices. In addition, present activities in materials science and engineering cover not only areas whose utility can be identified today, but also areas whose utility may be unforeseen. The services of materials scientists and engineers are required in a variety of engineering operations dealing, for example, with emerging energy systems, design of semiconductors and optoelectronic and nano devices, development of new technologies based on composites and high-temperature superconductivity, biomedical products, performance (e.g., quality, reliability, safety, energy efficiency) in automobile and aircraft components, improvement in nondestructive testing techniques, corrosion behavior in refineries, radiation damage in nuclear power plants, and fabrication of advanced materials.

The undergraduate major in Material Science Engineering (MSE) provides students with a thorough knowledge of basic engineering and scientific principles. The undergraduate curriculum in MSE includes (a) a core of Chemistry, Physics, and Mathematics; (b) basic Engineering courses; (c) Materials and Engineering core; and (d) technical courses in Materials Science, Engineering, and Sciences.

Because of the interdisciplinary nature of MSE and its intimate relations with other Engineering disciplines (Aerospace, Biomedical, Chemical, Civil, Computer, Electrical, Environmental, and Mechanical Engineering), qualified students will be able to satisfy in a straightforward manner the degree requirements of their Engineering major and the MSE major.

Admissions

Admissions

Undergraduate Major in Materials Science Engineering

Program Educational Objectives: Graduates of the Materials Science Engineering program will (1) establish a productive Materials Science and Engineering career in industry, government or academia; (2) apply critical reasoning and the requisite analytical/quantitative skills in seeking solutions to materials science and engineering problems; (3) promote innovation in materials development and design through effective leadership, skilled communications, and multidisciplinary teamwork; (4) exhibit a commitment to engineering ethics, environmental stewardship, continued learning, and professional development.

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High School Students: See School Admissions information.

Transfer Students: Preference will be given to junior-level applicants with the highest grades overall, and who have satisfactorily completed the following required courses: one year of approved calculus, one year of calculus-based physics with laboratories (mechanics, electricity and magnetism), completion of lower-division writing, one year of general chemistry (with laboratory), and one additional approved course for the major.

Students are encouraged to complete as many of the lower-division degree requirements as possible prior to transfer. Students who enroll at UCI in need of completing lower-division coursework may find that it will take longer than two years to complete their degrees. For further information, contact The Henry Samueli School of Engineering at 949-824-4334.
Requirements for the B.S. in Materials Science Engineering

All students must meet the University Requirements.
All students must meet the School Requirements.

Major Requirements

Mathematics and Basic Science Courses:

<table>
<thead>
<tr>
<th>Core Courses:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>ENGR 1A</td>
<td>General Chemistry for Engineers</td>
</tr>
<tr>
<td>or CHEM 1A</td>
<td>General Chemistry</td>
</tr>
<tr>
<td>CHEM 1B-1C</td>
<td>General Chemistry and General Chemistry</td>
</tr>
<tr>
<td>CHEM 1LC</td>
<td>General Chemistry Laboratory</td>
</tr>
<tr>
<td>MATH 2A-2B</td>
<td>Single-Variable Calculus and Single-Variable Calculus</td>
</tr>
<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
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<tr>
<td>MATH 3D</td>
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<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>PHYSICS 7C-7LC</td>
<td>Classical Physics and Classical Physics Laboratory</td>
</tr>
<tr>
<td>PHYSICS 7D-7E</td>
<td>Classical Physics and Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LD</td>
<td>Classical Physics Laboratory</td>
</tr>
</tbody>
</table>

Basic Engineering or Science Elective Courses:

Select four (4) units from the following:

| Bio SCI 93   | From DNA to Organisms |
| BME 50A      | Cell and Molecular Engineering |
| CHEM 51A     | Organic Chemistry |
| EECS 70B     | Network Analysis II |
| ENGR 7A-7B   | Introduction to Engineering I and Introduction to Engineering II 1 |
| ENGRCEE 20   | Introduction to Computational Problem Solving |
| ENGRMAE 52   | Computer-Aided Design |
| ENGRMAE 80   | Dynamics |
| or ENGRCEE 80| Dynamics |
| PHYSICS 51A  | Modern Physics |
| STATS 7      | Basic Statistics |

Engineering Topics Courses:

Students must complete a minimum of 22 units of engineering design.

<table>
<thead>
<tr>
<th>Core Courses:</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>CBEMS 65A</td>
<td>Thermodynamics of Materials</td>
</tr>
<tr>
<td>or ENGRMAE 91</td>
<td>Introduction to Thermodynamics</td>
</tr>
<tr>
<td>CBEMS 65B</td>
<td>Diffusion in Materials</td>
</tr>
<tr>
<td>or ENGRMAE 115</td>
<td>Applied Engineering Thermodynamics</td>
</tr>
<tr>
<td>CBEMS 154</td>
<td>Polymer Science and Engineering</td>
</tr>
<tr>
<td>CBEMS 155</td>
<td>Mechanical Behavior and Design Principles</td>
</tr>
<tr>
<td>CBEMS 155L</td>
<td>Mechanical Behavior Laboratory</td>
</tr>
<tr>
<td>CBEMS 160</td>
<td>Advanced Lab in Synthesis of Materials</td>
</tr>
<tr>
<td>CBEMS 164</td>
<td>X-ray Diffraction, Electron Microscopy, and Microanalysis</td>
</tr>
<tr>
<td>CBEMS 164L</td>
<td>X-ray Diffraction, Electron Microscopy, and Microanalysis Lab</td>
</tr>
<tr>
<td>CBEMS 165</td>
<td>Materials Kinetics and Phase Transformations</td>
</tr>
<tr>
<td>CBEMS 169</td>
<td>Electronic and Optical Properties in Materials</td>
</tr>
<tr>
<td>CBEMS 175</td>
<td>Design Failure Investigation</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
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<tr>
<td>CBEMS 189A-189B-189C</td>
<td>Senior Design Project I and Senior Design Project II and Senior Design Project III</td>
</tr>
<tr>
<td>EECS 70A</td>
<td>Network Analysis I</td>
</tr>
<tr>
<td>or ENGRMAE 60</td>
<td>Electric Circuits</td>
</tr>
<tr>
<td>ENGR 54</td>
<td>Principles of Materials Science and Engineering</td>
</tr>
<tr>
<td>ENGR 150</td>
<td>Mechanics of Structures</td>
</tr>
<tr>
<td>ENGRMAE 10</td>
<td>Introduction to Engineering Computations</td>
</tr>
<tr>
<td>ENGRMAE 30</td>
<td>Statics</td>
</tr>
<tr>
<td>or ENGR 30</td>
<td>Statics</td>
</tr>
<tr>
<td>or ENGRCEE 30</td>
<td>Statics</td>
</tr>
<tr>
<td>ENGRMAE 150L</td>
<td>Mechanics of Structures Laboratory</td>
</tr>
</tbody>
</table>

**Engineering Electives:**

Students must complete a minimum of five courses from:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>BME 50A</td>
<td>Cell and Molecular Engineering</td>
</tr>
<tr>
<td>BME 110A-110B</td>
<td>Biomechanics I and Biomechanics II</td>
</tr>
<tr>
<td>BME 111</td>
<td>Design of Biomaterials</td>
</tr>
<tr>
<td>BME 120</td>
<td>Sensory Motor Systems</td>
</tr>
<tr>
<td>CBEMS 110</td>
<td>Reaction Kinetics and Reactor Design</td>
</tr>
<tr>
<td>CBEMS 130</td>
<td>Separation Processes</td>
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<tr>
<td>CBEMS 141</td>
<td>Nano-Scale Materials and Applications</td>
</tr>
<tr>
<td>CBEMS 158</td>
<td>Ceramic Materials</td>
</tr>
<tr>
<td>CBEMS 163</td>
<td>Computer Techniques in Experimental Research</td>
</tr>
<tr>
<td>CBEMS 174</td>
<td>Semiconductor Device Packaging</td>
</tr>
<tr>
<td>CBEMS 191</td>
<td>Materials Outreach</td>
</tr>
<tr>
<td>CBEMS 199</td>
<td>Individual Study</td>
</tr>
<tr>
<td>EECS 70B</td>
<td>Network Analysis II</td>
</tr>
<tr>
<td>EECS 170LA</td>
<td>Electronics I Laboratory</td>
</tr>
<tr>
<td>EECS 170B</td>
<td>Electronics II</td>
</tr>
<tr>
<td>EECS 174</td>
<td>Semiconductor Devices</td>
</tr>
<tr>
<td>EECS 176</td>
<td>Fundamentals of Solid-State Electronics and Materials</td>
</tr>
<tr>
<td>EECS 180A</td>
<td>Engineering Electromagnetics I</td>
</tr>
<tr>
<td>ENGR 165</td>
<td>Advanced Manufacturing</td>
</tr>
<tr>
<td>ENGRMAE 106</td>
<td>Mechanical Systems Laboratory</td>
</tr>
<tr>
<td>ENGRMAE 145</td>
<td>Theory of Machines and Mechanisms</td>
</tr>
<tr>
<td>ENGRMAE 147</td>
<td>Vibrations</td>
</tr>
<tr>
<td>ENGRMAE 151</td>
<td>Mechanical Engineering Design</td>
</tr>
<tr>
<td>ENGRMAE 152</td>
<td>Introduction to Computer-Aided Engineering</td>
</tr>
<tr>
<td>ENGRMAE 155</td>
<td>Composite Materials and Structures</td>
</tr>
<tr>
<td>ENGRMAE 157</td>
<td>Lightweight Structures</td>
</tr>
<tr>
<td>ENGRMAE 170</td>
<td>Introduction to Control Systems</td>
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</tbody>
</table>

Students select, with the approval of a faculty advisor, any additional engineering topics courses needed to satisfy school and department requirements.

**Engineering Professional Topics Course:**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
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</thead>
<tbody>
<tr>
<td>ENGR 190W</td>
<td>Communications in the Professional World</td>
</tr>
</tbody>
</table>

(The nominal Materials Science Engineering program will require 183 units of courses to satisfy all university and major requirements. Because each student comes to UCI with a different level of preparation, the actual number of units will vary. Dual engineering majors are reminded that they are required to satisfy all requirements of both majors individually. Students should not assume that courses for one, such as senior design, will satisfy the requirements of the other, without prior approval.)

1 ENGR 7A-ENGR 7B is available only to lower-division students. Both ENGR 7A-ENGR 7B must be taken to be counted as a Basic Engineering or Science Elective course.
Students majoring in MSE may elect, with approval of their faculty advisor, to use available engineering electives to complete one of the following specializations.

**Specialization in Biomaterials:**
Requires a minimum of 14 units from:

- **BME 50A**  
  Cell and Molecular Engineering
- **BME 110A-110B**  
  Biomechanics I and Biomechanics II
- **BME 111**  
  Design of Biomaterials
- **BME 120**  
  Sensory Motor Systems
- **CBEMS 154**  
  Polymer Science and Engineering
- **CBEMS 199**  
  Individual Study

**Specialization in Electronics Processing and Materials:**
Requires a minimum of 14 units from:

- **CBEMS 174**  
  Semiconductor Device Packaging
- **CBEMS 199**  
  Individual Study (up to 3 units; or CBEMS H199, up to 3 units)
- **EECS 70B**  
  Network Analysis II
- **EECS 170LA**  
  Electronics I Laboratory
- **EECS 174**  
  Semiconductor Devices
- **ENGR 165**  
  Advanced Manufacturing

**Specialization in Materials and Mechanical Design:**
Requires a minimum of 14 units from:

- **CBEMS 199**  
  Individual Study (up to 3 units; or CBEMS H199, up to 3 units)
- **ENGRMAE 106**  
  Mechanical Systems Laboratory
- **ENGRMAE 145**  
  Theory of Machines and Mechanisms
- **ENGRMAE 147**  
  Vibrations
- **ENGRMAE 151**  
  Mechanical Engineering Design
- **ENGRMAE 152**  
  Introduction to Computer-Aided Engineering
- **ENGRMAE 155**  
  Composite Materials and Structures
- **ENGRMAE 157**  
  Lightweight Structures
- **ENGRMAE 170**  
  Introduction to Control Systems

**Planning a Program of Study**
A sample program of study chart for the major in Materials Science Engineering is available in the Undergraduate Student Affairs Office. Students should keep in mind that this program is based upon a sequence of prerequisites, beginning with adequate preparation in high school mathematics, physics, and chemistry. Students who are not adequately prepared, or who wish to make changes in the sequence for other reasons, must have their program approved by their faculty advisor. Materials Science Engineering majors must consult at least once every year with the academic counselors in the Undergraduate Student Affairs Office and with their faculty advisors.

**Sample Program of Study — Materials Science Engineering**

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<th>Freshman</th>
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<td>Fall</td>
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<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
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<tr>
<td>ENGR 1A</td>
<td>CHEM 1B</td>
<td>CHEM 1C</td>
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<tr>
<td>ENGRMAE 10</td>
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<thead>
<tr>
<th>Sophomore</th>
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<tr>
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<tr>
<td>MATH 3A</td>
<td>MATH 3D</td>
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<td>ENGR 30</td>
<td>CBEMS 65A</td>
<td>EECS 70A</td>
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<td>CBEMS 65B</td>
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<td>PHYSICS 7E</td>
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<thead>
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<th>Junior</th>
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<tr>
<td>ENGR 150</td>
<td>CBEMS 155</td>
<td>CBEMS 175</td>
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<tr>
<td>ENGRMAE 150L</td>
<td>CBEMS 155L</td>
<td>Engineering Elective</td>
</tr>
</tbody>
</table>
Minor in Materials Science Engineering

The interdisciplinary field of materials science and engineering has become critical to many emerging areas of advanced technology and their applications. As a result, there are needs and opportunities for engineers and scientists with education and training in materials science and engineering. The goal of the minor in Materials Science Engineering (MSE) is to provide students at UCI with such education and training that will enable them, upon graduation, to not only participate in projects or programs of an interdisciplinary nature but also address challenging societal needs and complex technological advances.

Admission

Admission in the MSE minor requires a minimum 2.5 overall UCI GPA. Students are required to complete all prerequisites for required courses and selected electives. In particular, students need to complete the following courses before applying:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 1A</td>
<td>General Chemistry</td>
</tr>
<tr>
<td>CHEM 1LE</td>
<td>Accelerated General Chemistry Lab</td>
</tr>
<tr>
<td>MATH 2D</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>MATH 3A</td>
<td>Introduction to Linear Algebra</td>
</tr>
<tr>
<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
</tr>
<tr>
<td>PHYSICS 7C</td>
<td>Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LC</td>
<td>Classical Physics Laboratory</td>
</tr>
<tr>
<td>PHYSICS 7D</td>
<td>Classical Physics</td>
</tr>
<tr>
<td>PHYSICS 7LD</td>
<td>Classical Physics Laboratory</td>
</tr>
</tbody>
</table>

Requirements for the Minor in Materials Science Engineering

The minor in Materials Science Engineering requires a total of seven courses—five required courses and two electives:

Required courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBEMS 155</td>
<td>Mechanical Behavior and Design Principles</td>
</tr>
<tr>
<td>ENGR 54</td>
<td>Principles of Materials Science and Engineering</td>
</tr>
</tbody>
</table>

Select three of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBEMS 165</td>
<td>Electronic and Optical Properties in Materials</td>
</tr>
<tr>
<td>CBEMS 169</td>
<td>Design Failure Investigation</td>
</tr>
<tr>
<td>CBEMS 175</td>
<td>Individual Study (contingent upon the availability of research positions in the Materials Science Engineering faculty’s research groups)</td>
</tr>
</tbody>
</table>

Electives:

Select two of the following:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BME 110A-110B</td>
<td>Biomechanics I and Biomechanics II</td>
</tr>
<tr>
<td>BME 111</td>
<td>Design of Biomaterials</td>
</tr>
<tr>
<td>BME 120</td>
<td>Sensory Motor Systems</td>
</tr>
<tr>
<td>CBEMS 141</td>
<td>Nano-Scale Materials and Applications</td>
</tr>
<tr>
<td>CBEMS 154</td>
<td>Polymer Science and Engineering</td>
</tr>
<tr>
<td>CBEMS 158</td>
<td>Ceramic Materials</td>
</tr>
<tr>
<td>CBEMS 163</td>
<td>Computer Techniques in Experimental Research</td>
</tr>
<tr>
<td>CBEMS 174</td>
<td>Semiconductor Device Packaging</td>
</tr>
<tr>
<td>CBEMS 191</td>
<td>Materials Outreach</td>
</tr>
</tbody>
</table>
For students who plan to pursue a graduate degree in MSE, it is highly recommended that they take CBEMS 165 in addition to two of the following courses: CBEMS 169, CBEMS 175, or CBEMS 199.

On This Page:

• Chemical and Biochemical Engineering
• Materials Science and Engineering

Graduate Study in Chemical and Biochemical Engineering

Chemical engineering uses the knowledge of chemistry, mathematics, physics, biology, and social sciences to solve societal problems such as energy, health, environment, food, clothing, shelter, and transportation. It serves a variety of processing industries whose vast array of products include chemicals, petroleum products, plastics, pharmaceuticals, foods, semiconductors, textiles, fuels, consumer products, and electronic and cryogenic materials. It also serves society to improve the environment by reducing and eliminating pollution. Chemical engineering is an engineering discipline that has its strongest ties with the molecular sciences. This is an important asset since sciences such as chemistry, molecular biology, biomedicine, and solid-state physics are providing the seeds for future technologies. Chemical engineering has a bright future as the discipline which will bridge science with engineering in multidisciplinary environments.

Biochemical Engineering is concerned with the processing of biological materials and processes that use biological agents such as living cells, enzymes, or antibodies. Biochemical Engineering, with integrated knowledge of the principles of biology and chemical engineering, plays a major engineering role in the rapidly developing area of biotechnology. Career opportunities in Biochemical Engineering are available in a variety of industries such as biotechnology, chemical, environmental, food, petrochemical, and pharmaceutical industries.

The principal objectives of the graduate curriculum in Chemical and Biochemical Engineering are to develop and expand students' abilities to solve new and more challenging engineering problems and to promote their skills in independent thinking and learning in preparation for careers in manufacturing, research, or teaching. These objectives are reached through a program of course work and research designed by each student with the assistance, advice, and approval of a primary faculty advisor and a faculty advisory committee. Programs of study leading to the M.S. and Ph.D. in Chemical and Biochemical Engineering are offered.

Recommended Background

It is strongly recommended that students have background and training in core Chemical Engineering topics (transport phenomena, thermodynamics, and reaction kinetics) as well as a strong background in mathematics, chemistry, and physics. A student who enters the program without undergraduate preparation in chemical engineering is required to take three to five additional prerequisite courses (MATH 3A and MATH 3D, and CBEMS 45B-CBEMS 45C, CBEMS 110, CBEMS 112, and CBEMS 125A).

Required Courses

Students are required to take the following courses for the M.S. and as a basis for the Ph.D. preliminary examination.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBEMS 210</td>
<td>Reaction Engineering</td>
</tr>
<tr>
<td>CBEMS 220</td>
<td>Transport Phenomena</td>
</tr>
<tr>
<td>CBEMS 230</td>
<td>Applied Engineering Mathematics I</td>
</tr>
<tr>
<td>CBEMS 240</td>
<td>Advanced Engineering Thermodynamics</td>
</tr>
</tbody>
</table>

1 For students who plan to pursue a graduate degree in MSE, it is highly recommended that they take CBEMS 165 in addition to two of the following courses: CBEMS 169, CBEMS 175, or CBEMS 199.
Electives
Graduate advisors should be consulted on the selection of elective courses. All graduate courses offered in CBEAMS are potential electives. Graduate-level courses offered in other Engineering departments and relevant graduate courses from other schools may also be taken as electives.

Additional Information
Students are required to consult the graduate student handbook for more specific details regarding the course, exam, and unit requirements.

Master of Science Degree
Two plans are available for the M.S. degree: a thesis option and a comprehensive examination option. Opportunities are available for part-time study toward the M.S.

Plan I: Thesis Option
For the M.S. thesis option, students are required to complete a research study of great depth and originality and obtain approval for a complete program of study. A minimum of 36 units is required for the M.S. The following are required: four required core courses, three quarters of CBEAMS 298 (Department Seminar), five additional graduate elective courses numbered 200–289 (or 200–295 if offered by other departments), related to their field of graduate studies, and approved by the graduate advisor. Up to two of these elective courses can be substituted by up to eight units of CBEAMS 296 (M.S. Thesis Research), and one of the elective courses may be substituted by an upper-division undergraduate elective course approved by the CBE graduate advisor.

Full-time graduate students must enroll in the departmental seminar each quarter during their first year unless exempt by petition.

Plan II: Comprehensive Examination Option
For the comprehensive examination option, students are required to complete 36 units of study and a comprehensive examination. The following are required: four required core courses, three quarters of CBEAMS 298 (Department Seminar), five additional graduate elective courses numbered 200–289 (or 200–295 if offered by other departments), related to their field of graduate studies, and approved by the graduate advisor. One of the elective courses may be substituted by an upper-division undergraduate elective course approved by the CBE graduate advisor. Research units (CBEAMS 296/CBEAMS 299) do not count towards the degree requirements of the Comprehensive Exam Option.

Full-time graduate students must enroll in the departmental seminar each quarter during their first year unless exempt by petition.

In addition to fulfilling the course requirements outlined above, it is a University requirement for the Master of Science degree that students fulfill a minimum of 36 units of study.

Doctor of Philosophy Degree
The Ph.D. in Chemical and Biochemical Engineering requires a commitment on the part of the student to dedicated study and collaboration with the faculty. Ph.D. students are selected on the basis of outstanding demonstrated potential and scholarship. Applicants must hold the appropriate prerequisite degrees from recognized institutions of high standing. After substantial preparation, Ph.D. candidates work under the supervision of faculty advisors. The process involves extended immersion in a research atmosphere and culminates in the production of original research results presented in a dissertation.

Milestones to be passed in the Ph.D. program in order to remain in good standing include the following: acceptance into a research group by the faculty advisor at the end of the student’s first year of study; successful completion of the Ph.D. preliminary examination by the end of the second year; preparation for pursuing research and the development of a research proposal culminating in passing the Qualifying Examination by the end of the third year of the Ph.D. program. The Qualifying Examination includes faculty evaluation of a written research dossier and an oral presentation. Students must advance to candidacy in their third year (second year for students who entered with a master’s degree).

The core course requirements for the Ph.D. are the same as for the M.S. Students must enroll in the departmental seminar each quarter during their first year unless exempt by petition. Ph.D. students must take two additional elective courses beyond the M.S. requirements. These courses are to be taken after the first year of graduate work, should be relevant to the Ph.D. dissertation topic, and must be selected in consultation with the research advisor and approved by the CBE graduate advisor. The preliminary examination is based on the four core courses and the ability of the student to comprehend and present a research paper. M.S. students who have completed a CBE M.S. degree elsewhere must have a written approval by the graduate advisor to waive required CBE core courses, if they have taken the equivalent courses elsewhere.

Final examination involves the oral presentation and defense of an acceptable dissertation in a seminar attended by students and faculty. The Ph.D. is granted upon the recommendation of the Doctoral Committee and the Dean of the Graduate Division. The normative time for completion of the Ph.D. is five years (four years for students who entered with a master’s degree). The maximum time permitted is seven years.

Relationship of M.S. and Ph.D. Programs
Students applying with the objective of a Ph.D. are admitted to the M.S./Ph.D. program only if they are likely to successfully complete a Ph.D. program. These students do not formally re-apply to the Ph.D. program after completing the M.S. Students who apply to the M.S.-only program must petition for the Ph.D. program if they desire to continue on for the Ph.D. Financial support is usually reserved for those students who plan to complete the Ph.D. The normative time to complete M.S. and Ph.D. degrees is two and five years, respectively.
Graduate Study in Materials Science and Engineering

Materials Science and Engineering focuses on the development of new materials and new applications for materials in engineering. Current research programs include nanomaterials, nanostructures, nanoelectronics, nanodevices, nanocharacterization, device/system packaging materials, materials for fuel cells and related alternative energy systems, biocompatible materials, soft materials such as biological materials and polymeric materials, electronic and photonic materials, hybrid materials, interfacial engineering of materials, and multifunctional materials. Faculty with relevant research are affiliated with the Integrated Nanofabrication Research Facility (INRF), the National Fuel Cell Research Center (NFCRC), the California Institute for Telecommunications and Information Technology (Calit2), the Advanced Power and Energy Program (APEP), and the Laboratory for Electron and X-ray Instrumentation (LEXI), among others.

The MSE graduate degree program is hosted by the Department of Chemical Engineering and Materials Science (ChEMS). Faculty who may serve as advisors are listed as affiliated with the ChEMS Department and include faculty with strong materials science and engineering research programs from other departments. The formal degree that is awarded upon successful completion of the program is either the M.S. or Ph.D. in Materials Science and Engineering.

Recommended Background

Given the nature of Materials Science and Engineering as a cross-disciplinary program, students having a background, and suitable training, in Materials, Engineering (Mechanical, Electrical, Civil, Chemical, Aerospace), and the Physical Sciences (Physics, Chemistry, Geology) are encouraged to participate. A student with an insufficient background may be required to take remedial undergraduate courses. Recommended background courses include an introduction to materials, thermodynamics, mechanical behavior, and electrical/optical/magnetic behavior.

Specific Fields of Emphasis

The Materials faculty at UCI have special interest and expertise in all areas of modern materials and technologies, including biomaterials, energy materials, advanced ceramics, polymers and nanocomposite materials, structural and nanostructured metallic materials, micro/nano-device materials, device/system packaging materials, and multifunctional materials.

Required Courses

Students are required to take one course from each area for the M.S. and as a basis for the Ph.D. preliminary examination.

Crystal Structure and Defects:

| ENGRMSE 200 | Crystalline Solids: Structure, Imperfections, and Properties |

Electrical and Optical Behavior:

| ENGRMSE 205 | Materials Physics |

Mechanical Behavior:

| ENGRMSE 256A | Mechanical Behavior of Engineering Materials |

Thermodynamics and Kinetics:

| ENGRMSE 265 | Phase Transformations |

Electives

Faculty advisors should be consulted on the selection of elective courses. All graduate courses offered in CBEMS are potential electives. Graduate-level courses offered in other Engineering departments and relevant graduate courses from other schools may also be taken as electives.

Master of Science Degree

The M.S. reflects achievement of an advanced level of competence for professional practice of materials science and engineering. Two options are available: a thesis option and a comprehensive examination option.

Plan I: Thesis Option

For the M.S. thesis option, students are required to complete a research study of great depth and originality and obtain approval for a complete program of study. A committee of three full-time faculty members is appointed to guide development of the thesis. A minimum of 36 units is required for the M.S.

For the thesis option, the following are required: four required core courses; three quarters of CBEMS 298 (Department Seminar), five additional graduate elective courses numbered 200–289 (or 200-295 if offered by other departments), related to their field of graduate studies, and approved by the graduate advisor. Up to two of these elective courses can be substituted by up to eight units of CBEMS 296 (M.S. Thesis Research), and one of these elective courses may be substituted by an upper-division undergraduate elective course approved by the MSE graduate advisor.

Full-time graduate students must enroll in the departmental seminar each quarter during their first year unless exempt by petition.

Plan II: Comprehensive Examination Option

For the comprehensive examination option, students are required to complete 36 units of study and a comprehensive examination.
The following are required: four required core courses; three quarters of CBEMS 298 (Department Seminar), and a minimum of five additional graduate elective courses numbered 200–299 (or 200-295 if offered by other departments), related to their field of graduate studies, and approved by the graduate advisor. One of the elective courses may be substituted by an upper-division undergraduate elective course approved by the MSE graduate advisor.

Research units (CBEMS 296/CBEMS 299) do not count towards the degree requirements of the Comprehensive Exam Option. Full-time graduate students must enroll in the departmental seminar each quarter during their first year unless exempt by petition.

In addition to fulfilling the course requirements outlined above, it is a University requirement for the Master of Science degree that students fulfill a minimum of 36 units of study.

**Doctor of Philosophy Degree**

The Ph.D. in Materials Science and Engineering requires a commitment on the part of the student to dedicated study and collaboration with the faculty. Ph.D. students are selected on the basis of outstanding demonstrated potential and scholarship. Applicants must hold the appropriate prerequisite degrees from recognized institutions of high standing. After substantial preparation, Ph.D. candidates work under the supervision of faculty advisors. The process involves extended immersion in a research atmosphere and culminates in the production of original research results presented in a dissertation. Milestones to be passed in the Ph.D. program in order to remain in good standing include the following: acceptance into a research group by the faculty advisor at the end of the student’s first year of study; successful completion of the Ph.D. preliminary examination by the end of the second year; preparation for pursuing research and the development of a research proposal culminating in passing the Qualifying Examination by the end of the third year of the Ph.D. program. The Qualifying Examination includes faculty evaluation of a written research dossier and an oral presentation. Students must advance to candidacy in their third year (second year for students who entered with a master’s degree).

The core course requirements for the Ph.D. are the same as for the M.S. Students must enroll in the departmental seminar each quarter during their first year unless exempt by petition. Ph.D. students must take two additional elective courses beyond the M.S. requirements. These courses are to be taken after the first year of graduate work, should be relevant to the Ph.D. dissertation topic, and must be selected in consultation with the research advisor and approved by the MSE graduate advisor. The preliminary examination is based on the four core courses for the M.S. Students who have completed an MSE M.S. elsewhere must have a written approval by the graduate advisor to waive required MSE core courses, if they have taken the equivalent courses elsewhere.

Final examination involves the oral presentation and defense of an acceptable dissertation in a seminar attended by students and faculty. The Ph.D. is granted upon the recommendation of the Doctoral Committee and the Dean of the Graduate Division. The normative time for completion of the Ph.D. is five years (four years for students who entered with a master’s degree). The maximum time permitted is seven years.

**Relationship of M.S. and Ph.D. programs**

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**Faculty**

Nancy A. Da Silva, Ph.D. California Institute of Technology, Professor of Chemical Engineering and Materials Science; Biomedical Engineering (molecular biotechnology)

James Earthman, Ph.D. Stanford University, Professor of Chemical Engineering and Materials Science; Biomedical Engineering (biomaterials, dental and orthopaedic implants, green materials, nanocrystalline alloys, deformation and damage processes)

Alon A. Gorodetsky, Ph.D. California Institute of Technology, Assistant Professor of Chemical Engineering and Materials Science; Chemistry (organic photovoltaics, electrical biosensors, nanotechnology, DNA, materials chemistry)

Allon I. Hochbaum, Ph.D. University of California, Berkeley, Assistant Professor of Chemical Engineering and Materials Science; Chemistry (nanoscale materials and hybrid bio-inorganic devices for applications in clean energy)

Juan Hong, Ph.D. Purdue University, Professor Emeritus of Chemical Engineering and Materials Science

Enrique Lavernia, Ph.D. Massachusetts Institute of Technology, UCI Provost and Distinguished Professor of Chemical Engineering and Materials Science (nanostructured materials, additive manufacturing, powder metallurgy, mechanical behavior)

Han Li, Ph.D. University of California, Los Angeles, Assistant Professor of Chemical Engineering and Materials Science (synthetic biology, microbiology, protein engineering, fermentation and microbial production processes)

Henry C. Lim, Ph.D. Northwestern University, Professor Emeritus of Chemical Engineering and Materials Science
Martha L. Mecartney, Ph.D. Stanford University, Professor of Chemical Engineering and Materials Science (ceramics for energy applications and for use in extreme environments, interfacial design for enhanced physical properties, transmission electron microscopy)

Farghali A. Mohamed, Ph.D. University of California, Berkeley, Professor Emeritus of Chemical Engineering and Materials Science (mechanical behavior of engineering materials such as metals, composites and ceramics, the correlation between behavior and microstructure, creep and superplasticity, mechanisms responsible for strengthening and fracture)

Ali Mohraz, Ph.D. University of Michigan, Associate Professor of Chemical Engineering and Materials Science (understand and exploit colloidal interactions, chemistry, assembly, and response to external fields to design microstructured materials with enhanced functionality for composites, biomimetic applications, alternative energy, environmental remediation)

Daniel R. Mumm, Ph.D. Northwestern University, Associate Professor of Chemical Engineering and Materials Science (development of materials for power generation systems, propulsion, integrated sensing, advanced vehicle concepts and platform protection)

Mikael Nilsson, Ph.D. Chalmers University of Technology, Associate Professor of Chemical Engineering and Materials Science, Chemistry (actinide chemistry, solvent extraction fundamental chemistry and process development, extraction and detection equipment development, radiolysis and phase composition of organic solvent)

Xiaoping Pan, Ph.D. Saarlandes University, Henry Samueli Endowed Chair and Professor of Chemical Engineering and Materials Science; Physics and Astronomy (transmission electron microscopy and materials science)

Regina Ragan, Ph.D. California Institute of Technology, Endowed Chair for the Center for Diversity in Engineering Education and Associate Professor of Chemical Engineering and Materials Science (exploration and development of novel material systems for nanoscale electronic and optoelectronic devices)

Elizabeth L. Read, Ph.D. University of California, Berkeley, Assistant Professor of Chemical Engineering and Materials Science; Molecular Biology and Biochemistry (dynamics of complex biochemical systems, regulation of immune responses)

Julie Schoenung, Ph.D. Massachusetts Institute of Technology, Professor of Chemical Engineering and Materials Science (materials selection, green engineering, materials processing and characterization, nanostructured materials, structure-property relationships)

Frank G. Shi, Ph.D. California Institute of Technology, Professor of Chemical Engineering and Materials Science (optoelectronic devices and materials, optoelectronic device packaging materials, optoelectronic medical devices and packaging, white LED technologies, high power LED packaging)

Vasan Venugopalan, ScD Massachusetts Institute of Technology, Department Chair and Professor of Chemical Engineering and Materials Science; Biomedical Engineering; Mechanical and Aerospace Engineering; Surgery (laser-induced thermal, mechanical and radiative transport processes for application in medical diagnostics, therapeutics, biotechnology, micro-electro-mechanical systems (MEMS))

Szu-Wen Wang, Ph.D. Stanford University, Professor of Chemical Engineering and Materials Science; Biomedical Engineering (combining principles of self-assembly with nature-inspired macromolecular systems to engineer new materials and therapeutic strategies)

Albert Fan Yee, Ph.D. University of California, Berkeley, Professor of Chemical Engineering and Materials Science; Biomedical Engineering; Chemistry (materials science aspects of polymers and soft materials, particularly on how they are used to impact nanotechnology)

**Affiliate Faculty**

Shane Ardo, Ph.D. Johns Hopkins University, Assistant Professor of Chemistry; Chemical Engineering and Materials Science (inorganic and organometallic, physical chemistry and chemical physics, polymer, materials, nanoscience)

Elliot L. Botvinick, Ph.D. University of California, San Diego, Associate Professor of Surgery; Biomedical Engineering; Chemical Engineering and Materials Science (laser microbeams, cellular mechanotransduction, mechanobiology)

Peter J. Burke, Ph.D. Yale University, Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science (nano-electronics, bio-nanotechnology)

Michelle Digman, Ph.D. University of Illinois at Chicago, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science; Developmental and Cell Biology (quantitative imaging techniques to study spatial-temporal dynamics of signaling protein networks in live cells and tissues)

Aaron P. Esser-Kahn, Ph.D. University of California, Berkeley, Associate Professor of Chemistry; Biomedical Engineering; Chemical Engineering and Materials Science (chemical biology, organic and synthetic, polymer, materials, nanoscience)

Stanley B. Grant, Ph.D. California Institute of Technology, Professor of Civil and Environmental Engineering; Chemical Engineering and Materials Science (environmental engineering, inland and coastal water quality, coagulation and filtration of colloidal contaminants, environmental microbiology)
Anna Grosberg, Ph.D. California Institute of Technology, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science (computational modeling of biological systems, biomechanics, cardiac tissue engineering)

Zhibin Guan, Ph.D. University of North Carolina at Chapel Hill, Professor of Chemistry; Biomedical Engineering; Chemical Engineering and Materials Science (chemical biology, organic and synthetic, polymer, materials, nanoscience)

Jered Hau, Ph.D. University of Pennsylvania, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science (nanotechnology, molecular engineering, computational simulations, targeted drug delivery, clinical cancer detection)

Michelle Khine, Ph.D. University of California, Berkeley, Professor of Biomedical Engineering; Chemical Engineering and Materials Science (development of novel nano- and micro-fabrication technologies and systems for single cell analysis, stem cell research, in-vitro diagnostics)

Young Jik Kwon, Ph.D. University of Southern California, Professor of Pharmaceutical Sciences; Biomedical Engineering; Chemical Engineering and Materials Science; Molecular Biology and Biochemistry (gene therapy, drug delivery, cancer-targeted therapeutics, combined molecular imaging and therapy, cancer vaccine)

Matthew Law, Ph.D. University of California, Berkeley, Associate Professor of Chemistry; Chemical Engineering and Materials Science (inorganic and organometallic, physical chemistry and chemical physics, polymer, materials, nanoscience)

Jaeho Lee, Ph.D. Stanford University, Assistant Professor of Mechanical and Aerospace Engineering; Chemical Engineering and Materials Science (nanofabrication and thermoelectric energy conversion)

Guann-Pyng Li, Ph.D. University of California, Los Angeles, Director of the UCI Division of the California Institute for Telecommunications and Information Technology (Calit2), Director of the Integrated Nanosystems Research Facility and Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science (high-speed semiconductor technology, optoelectronic devices, integrated circuit fabrication and testing)

Mo Li, Ph.D. University of Michigan, Assistant Professor of Civil and Environmental Engineering; Chemical Engineering and Materials Science (responsive materials, multifunctional materials and structures, fracture mechanics, infrastructure sustainability)

Wendy F. Liu, Ph.D. Johns Hopkins University, Assistant Professor of Biomedical Engineering; Chemical Engineering and Materials Science (biomaterials, microdevices in cardiovascular engineering, cell-cell and cell-micro-environment interactions, cell functions and controls)

John S. Lowengrub, Ph.D. Courant Institute of Mathematical Sciences, UCI Chancellor's Professor of Mathematics; Biomedical Engineering; Chemical Engineering and Materials Science (applied and computational mathematics, mathematical and computational biology)

Ray Luo, Ph.D. University of Maryland, College Park, Professor of Molecular Biology and Biochemistry; Biomedical Engineering; Chemical Engineering and Materials Science (protein structure, noncovalent associations involving proteins)

Marc J. Madou, Ph.D. Gent University, UCI Chancellor's Professor of Mechanical and Aerospace Engineering; Biomedical Engineering; Chemical Engineering and Materials Science (fundamental aspects of micro/nano-electro-mechanical systems (MEMS/NEMS), biosensors, nanofluidics, biomimetics)

Diego Rosso, Ph.D. University of California, Los Angeles, Director of the UCI Water-Energy Nexus Center (WEX) and Associate Professor of Civil and Environmental Engineering; Chemical Engineering and Materials Science (environmental process engineering, mass transfer, wastewater treatment, carbon- and energy-footprint analysis)

Timothy Rupert, Ph.D. Massachusetts Institute of Technology, Assistant Professor of Mechanical and Aerospace Engineering; Chemical Engineering and Materials Science (mechanical behavior, nanomaterials, structure property relationships, microstructural stability, grain boundaries and interfaces, materials characterization)

Suzanne B. Sandmeyer, Ph.D. University of Washington, Grace Beekhuis Bell Chair in Biological Chemistry and Professor of Biological Chemistry; Chemical Engineering and Materials Science; Microbiology and Molecular Genetics (retroelements, metabolic molding, genomics)

Kenneth J. Shea, Ph.D. Pennsylvania State University, Professor of Chemistry; Chemical Engineering and Materials Science (analytical, chemical biology, organic and synthetic, polymer, materials, nanoscience)

Lizhi Sun, Ph.D. University of California, Los Angeles, Professor of Civil and Environmental Engineering; Chemical Engineering and Materials Science (micro- and nano-mechanics, composites and nanocomposites, smart materials and structures, multiscale modeling, elastography)

William C. Tang, Ph.D. University of California, Berkeley, Professor of Biomedical Engineering; Chemical Engineering and Materials Science; Electrical Engineering and Computer Science (micro-electro-mechanical systems (MEMS) nanoscale engineering for biomedical applications, microsystems integration, microimplants, microbiomechanics, microfluidics)
Lorenzo Valdevit, Ph.D. Princeton University, *Director of the Institute for Design and Manufacturing Innovation (IDMI) and Associate Professor of Mechanical and Aerospace Engineering; Chemical Engineering and Materials Science* (multifunctional sandwich structures, thermal protection systems, morphing structures, active materials, MEMS, electronic packaging, cell mechanics)

H. Kumar Wickramasinghe, Ph.D. University of London, *Henry Samueli Endowed Chair in Engineering and Department Chair and Professor of Electrical Engineering and Computer Science; Biomedical Engineering; Chemical Engineering and Materials Science* (nanoscale measurements and characterization, scanning probe microscopy, storage technology, nano-bio measurement technology)

Yoon Jin Won, Ph.D. Stanford University, *Assistant Professor of Mechanical and Aerospace Engineering; Center for Educational Partnerships* (multi-scale structures for thermal and energy applications, in particular fabrication, characterization, and integration of structured materials)

**Chemical Engr and Materials Sci Courses**

**CBEMS 45A. Chemical Processing and Materials Balances. 4 Units.**
Introduction to chemical engineering and the industries where chemical engineers play vital roles. Problem-solving skills and techniques. Quantitative calculations and applications using mass and energy balances. Stoichiometric equations, multiple bypasses, and others in process industries.

(Design units: 0)
Prerequisite: MATH 2B and CHEM 1B and PHYSICS 7C

Restriction: Chemical Engineering Majors have first consideration for enrollment. Environmental Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

**CBEMS 45B. Chemical Processing and Energy Balances. 3 Units.**
Principles of thermodynamics: definitions, basic concepts, and laws; property relationships; construction of thermodynamic charts and tables; energy balances; phase and chemical equilibria; combined mass and energy balances.

(Design units: 0)
Prerequisite: (CBEMS 45A or PHYSICS 7E) and MATH 3A. CBEMS 45A with a grade of C- or better

Overlaps with ENGRMAE 91, CBEMS 65A.

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

**CBEMS 45C. Chemical Engineering Thermodynamics. 4 Units.**
Elements of chemical engineering thermodynamics, including equilibrium and stability; equations of state; generalized correlations of properties of materials; properties of ideal and non-ideal mixtures; thermodynamics of real solutions; ideal and non-ideal phase equilibria; chemical equilibria for ideal and non-ideal solutions.

(Design units: 1)
Prerequisite: (EECS 10 or ENGRMAE 10) and MATH 2D and CBEMS 45B. CBEMS 45B with a grade of C- or better

Overlaps with ENGRMAE 115, CBEMS 65B.

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

**CBEMS 50L. Principles of Materials Science and Engineering. 2 Units.**
Introduction to the experimental techniques to characterize the properties of engineering materials. Emphasis on understanding the influence of microstructure on elastic, plastic, and fracture behavior. Topics include microstructure characterization, heat treatment, grain size effect, precipitation hardening, and impact loading. Materials fee.

(Design units: 0)

Corequisite: ENGR 54

Restriction: Materials Science Engineering Majors have first consideration for enrollment.
CBEMS 65A. **Thermodynamics of Materials.** 4 Units.
Treatment of the laws of thermodynamics and their application in understanding properties and equilibrium states of engineering materials. Develops relationships pertaining to multiphase equilibrium and presents graphical constructions for interpretation of phase diagrams. Statistical thermodynamics in relation to materials phenomena.

(Design units: 0)

Prerequisite: (ENGR 1A or CHEM 1A) and PHYSICS 7C

Overlaps with CBEMS 45B, ENGRMAE 91.

Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 65B. **Diffusion in Materials.** 4 Units.

(Design units: 0)

Prerequisite: CBEMS 65A. CBEMS 65A with a grade of C- or better

Overlaps with CBEMS 45C, ENGRMAE 115.

Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 110. **Reaction Kinetics and Reactor Design.** 4 Units.
Introduction to quantitative analysis of chemical reactions and chemical reactor design. Reactor operations including batch, continuous stirred tank, and tubular reactor. Homogeneous and heterogeneous reactions.

(Design units: 2)

Prerequisite: CHEM 1C and MATH 3D and CBEMS 45B and CBEMS 45C. CBEMS 45B with a grade of C- or better. CBEMS 45C with a grade of C- or better

Restriction: Chemical Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 112. **Introduction to Biochemical Engineering.** 3 Units.
Application of engineering principles to biochemical processes. Topics include microbial pathways, energetics and control systems, enzyme and microbial kinetics and the design and analysis of biological reactors.

(Design units: 1)

Prerequisite: CBEMS 110 and CHEM 1C and MATH 3D

Restriction: Chemical Engineering Majors have first consideration for enrollment.

CBEMS 115. **Kinetics of Biochemical Networks.** 4 Units.
Principles from statistical mechanics, thermodynamics, and chemical kinetics applied to biochemical systems, from fundamental processes such as receptor-ligand binding and enzyme catalysis, to complex cellular functions including signal transduction and gene regulation.

(Design units: 0)

Restriction: Upper-division students only.

Concurrent with CBEMS 215.
CBEMS 119. Biomaterials: Structural Biology and Assembly. 4 Units.
Application of fundamental concepts in structural biology (proteins, DNA/RNA, carbohydrates, lipids), biomolecular thermodynamics, and molecular interactions to the design of novel biomaterials via self-assembly.

(Design units: 0)
Prerequisite: CBEMS 45C and CBEMS 110
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.
Concurrent with CBEMS 219.

CBEMS 125A. Momentum Transfer. 4 Units.
Fluid statics, surface tension, Newton’s law of viscosity, non-Newtonian and complex flows, momentum equations, laminar and turbulent flow, velocity profiles, flow in pipes and around objects, piping systems design, pumps and mixing, and other applications to chemical and related industries.

(Design units: 0)
Prerequisite: (CBEMS 45C or CBEMS 65B) and MATH 3D. CBEMS 45C with a grade of C- or better. CBEMS 65B with a grade of C- or better
Overlaps with ENGRMAE 130A, ENGRCEE 170.
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 125B. Heat Transfer. 3 Units.
Principles of conduction, radiation, and convection of heat; phenomenological rate laws, differential and macroscopic energy balances; heat transfer rates, steady state and unsteady state conduction, convection; applications to chemical and related industries.

(Design units: 1)
Prerequisite: CBEMS 125A. CBEMS 125A with a grade of C- or better
Overlaps with CBEMS 120B, ENGRMAE 120.
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 125C. Mass Transfer. 3 Units.
Molecular and continuum approaches to diffusion and convection in multi-component mixtures; steady state, quasi-steady state and transient mass transfer; effect of reactions on mass transfer; convective mass transfer; simultaneous mass, heat and momentum transfer; applications to chemical and related industries.

(Design units: 1)
Prerequisite: CBEMS 125B
Overlaps with BME 150.
Restriction: Chemical Engineering Majors have first consideration for enrollment.

CBEMS 128. Introduction to Numerical Methods in Engineering. 3 Units.
An introduction to the fundamentals of numerical analysis and the computer algorithms in MATLAB for the solution of engineering problems, with emphasis on problems arising in chemical engineering thermodynamics, transport phenomena, and reaction engineering.

(Design units: 0)
Prerequisite: CBEMS 45C
CBEMS 130. Separation Processes. 4 Units.
Application of equilibria and mass and energy balances for design of separation processes. Use of equilibrium laws for design of distillation, absorption, stripping, and extraction equipment. Design of multicomponent separators.

(Design units: 3)

Prerequisite: CBEMS 45B and CBEMS 45C. CBEMS 45B with a grade of C- or better. CBEMS 45C with a grade of C- or better

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 133. Nuclear and Radiochemistry. 4 Units.
Advanced treatment of nuclear structure, nuclear reactions, and radioactive-decay processes. Introduction to nuclear activation analysis, isotope effects, radiation chemistry, hot-atom chemistry, nuclear age-dating methods, nuclear reactors, and nuclear power.

(Design units: 0)

Prerequisite: (CHEM M3C or CHEM 1C or CHEM H2C) and MATH 2D

Same as CHEM 133.
Overlaps with CHEM 170.

Restriction: Chemistry Majors have first consideration for enrollment. Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment. CHEM 133 and CHEM 170 cannot both be taken for credit.

Concurrent with CBEMS 233 and CHEM 233.

CBEMS 135. Chemical Process Control. 4 Units.
Dynamic responses and control of chemical process equipment, dynamic modeling of chemical processes, linear system analysis, analyses and design of feedback loops and advanced control systems.

(Design units: 1)

Prerequisite: CBEMS 110 and CBEMS 125B and CBEMS 125C

Restriction: Chemical Engineering Majors have first consideration for enrollment.

CBEMS 140A. Chemical Engineering Laboratory I. 4 Units.
Experimental study of thermodynamics, fluid mechanics, and heat and mass transfer. Operation and evaluation of process equipment, data analysis. Materials fee.

(Design units: 1)

Prerequisite: CBEMS 110 and CBEMS 125C

Restriction: Chemical Engineering Majors have first consideration for enrollment.

CBEMS 140B. Chemical Engineering Laboratory II. 4 Units.
Continuation of the CBEMS 140A covering mass transfer operations such as distillation, absorption, extraction, etc. Rate and equilibria studies in simple chemical systems with and without reaction. Study of chemical process. Materials fee.

(Design units: 3)

Prerequisite: CBEMS 130 and CBEMS 135 and CBEMS 140A

Restriction: Chemical Engineering Majors have first consideration for enrollment.

CBEMS 141. Nano-Scale Materials and Applications. 4 Units.
Overview of the chemistry, physics, and applications of nanometer-scale materials. Explore the effects of composition, bonding, and confinement on physical properties of nanomaterials, their chemical syntheses, and their device physics in electronic, optoelectronic, and energy technologies.

(Design units: 1)

Prerequisite: (ENGR 1A or CHEM 1A) and MATH 2B and PHYSICS 7D

Concurrent with CBEMS 241.
CBEMS 143. Chemistry and Technology for the Nuclear Fuel Cycle. 4 Units.
Introduces basic concepts of nuclear chemistry and focuses on chemical engineering aspects of the nuclear power industry. A broad survey of the nuclear fuel cycle (uranium processing, reactor concepts, spent fuel treatment and repositories) will be given.

(Design units: 0)
Concurrent with CBEMS 243.

CBEMS 149A. Chemical Engineering Design I. 3 Units.
Introduction to process design; flow sheets for chemical processes; synthesis of multicomponent separation sequences and reaction paths; synthesis of heat exchange networks; computer-aided design and simulation of processes and components pacts.

(Design units: 2)
Prerequisite: CBEMS 110 and CBEMS 125C and CBEMS 130
Restriction: Chemical Engineering Majors only.

CBEMS 149B. Chemical Engineering Design II. 3 Units.
Application of chemical engineering basics to practical design problems; process economics; process safety; environmental impacts; a major team design project with progress reports, oral presentation, and technical report with engineering drawings and economics.

(Design units: 3)
Prerequisite: CBEMS 149A
Restriction: Chemical Engineering Majors only.

CBEMS 154. Polymer Science and Engineering. 4 Units.
An introduction to physical aspects of polymers, including configuration and conformation of polymer chains and characterization techniques; crystallinity viscoelasticity, rheology and processing.

(Design units: 1)
Prerequisite: (ENGR 1A or CHEM 1A) and (CHEM 1B and CHEM 1C and ENGR 54)
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.
Concurrent with ENGRMSE 254.

CBEMS 155. Mechanical Behavior and Design Principles. 4 Units.
Principles governing structure and mechanical behavior of materials, relationship relating microstructure and mechanical response with application to elasticity, plasticity, yielding, necking, creep, and fracture of materials. Introduction to experimental techniques to characterize the properties of materials. Design parameters.

(Design units: 2)
Prerequisite: ENGR 54
Same as ENGRMAE 156.
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment. Mechanical Engineering Majors have first consideration for enrollment.

CBEMS 155L. Mechanical Behavior Laboratory. 1 Unit.
Introduction to experimental techniques to characterize mechanical properties of materials. Emphasis on correlations between property and microstructure. Experiments include: plastic stability in tension, effect of grain size on flow stress at low and high temperatures, superplasticity, nanostructured materials. Materials fee.

(Design units: 0)
Corequisite: CBEMS 155
Prerequisite: ENGR 54
Restriction: Materials Science Engineering Majors have first consideration for enrollment.
CBEMS 158. Ceramic Materials. 3 Units.
A technical elective for students interested in the materials area. Topics covered include structure and properties of ceramics, and design with ceramics.
(Design units: 1)
Prerequisite: ENGR 54
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 160. Advanced Lab in Synthesis of Materials. 4 Units.
Synthesis and characterization of organic and inorganic materials including polymers and oxides. Techniques include electron and scanning probe microscopy, gel permeation chromatography, X-ray diffraction, porosimetry, and thermal analysis. Materials fee.
(Design units: 0)
Prerequisite: ENGR 54 or (CHEM 131A and CHEM 131B)
Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 163. Computer Techniques in Experimental Research. 4 Units.
Principles and practical guidelines of automated materials testing. Computer fundamentals, programming languages, data acquisition and control hardware, interfacing techniques, programming strategies, data analysis, data storage, safeguard procedures.
(Design units: 1)
Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.
Concurrent with ENGRMSE 263.

CBEMS 164. X-ray Diffraction, Electron Microscopy, and Microanalysis. 3 Units.
Material characterization using X-ray diffraction and scanning electron microscopy (SEM). Topics include X-ray diffraction and analysis; SEM imaging and microanalysis. Materials fee.
(Design units: 1)
Prerequisite: ENGR 54
Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 164L. X-ray Diffraction, Electron Microscopy, and Microanalysis Lab. 2 Units.
Material characterization using X-ray diffraction and scanning electron microscopy (SEM). Topics include X-ray diffraction and analysis; SEM imaging and microanalysis.
(Design units: 1)
Corequisite: CBEMS 164
Prerequisite: ENGR 54
Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 165. Materials Kinetics and Phase Transformations. 3 Units.
Treatment of the kinetics of solid-state reactions and reactions at interfaces. Thermodynamics and kinetics of phase transformations, including solidification processes, diffusional and diffusionless phase transformations.
(Design units: 0)
Prerequisite: ENGR 54 and (ENGRMAE 91 or CBEMS 45C or CBEMS 65B). ENGRMAE 91 with a grade of C- or better. CBEMS 45C with a grade of C- or better. CBEMS 65B with a grade of C- or better
Restriction: Materials Science Engineering Majors have first consideration for enrollment.
CBEMS 169. Electronic and Optical Properties in Materials. 4 Units.
Covers the electronic, optical, and dielectric properties of crystalline and amorphous materials to provide a foundation of the underlying physical principles governing the properties of existing and emerging electronic and photonic materials.

(Design units: 1)

Prerequisite: PHYSICS 7D and PHYSICS 7E and MATH 3A and MATH 3D

Restriction: Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 174. Semiconductor Device Packaging. 3 Units.
Introduction to the semiconductor device packaging and assembly process. Electrical, thermal, optical, and mechanical aspects of package design and reliability. Special topics on optoelectronics packaging will be covered.

(Design units: 1)

Prerequisite: CBEMS 45B

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 175. Design Failure Investigation. 4 Units.
Survey of mechanisms by which devices fail, including overload, fatigue, corrosion, and wear. Use of fractography and other evidence to interpret failure modes and specify design/manufacturing changes. Students redesign failed parts or structures based on actual parts and/or case histories.

(Design units: 2)

Prerequisite: ENGR 54

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 189A. Senior Design Project I. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials fee.

(Design units: 2)

Grading Option: In progress only.

Restriction: Seniors only. Materials Science Engineering Majors only. CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.

CBEMS 189B. Senior Design Project II. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials fee.

(Design units: 3)

Prerequisite: CBEMS 189A

Grading Option: In progress only.

Restriction: Seniors only. Materials Science Engineering Majors only. CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.

CBEMS 189C. Senior Design Project III. 3 Units.
Group supervised senior design projects that deal with materials selection in engineering design and that involve case studies in ethics, safety, design, failure modes, new products, and patents. Activities conclude with a presentation of the projects. Materials fee.

(Design units: 3)

Prerequisite: CBEMS 189B

Restriction: Seniors only. Materials Science Engineering Majors only. CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.
CBEMS 190. Materials Selection and Design. 4 Units.
Materials selection to meet specific requirements. Statistical considerations. Engineering economics. Seminars on materials selection and design by industry leaders and faculty.

(Design units: 3)

Restriction: Seniors only. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 191. Materials Outreach. 3 Units.
Demonstrates major concepts in Materials Science and Engineering. Concepts of materials engineering covered include deformation in crystalline solids, effects of heat treatment on mechanical properties, thermal barrier materials, composites design, mechanical behavior of polymers, superconductivity in ceramics.

(Design units: 1)

Prerequisite: ENGR 54

Repeatability: May be taken for credit 4 times.

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 195. Special Topics in Chemical Engineering and Materials Science. 1-4 Units.
Studies in selected areas of Chemical Engineering and Materials Science. Topics addressed vary each quarter.

(Design units: 0)

Prerequisite: Prerequisites vary.

Repeatability: Unlimited as topics vary.

CBEMS 198. Group Study. 1-4 Units.
Group study of selected topics in engineering.

(Design units: 1-4)

Repeatability: May be repeated for credit unlimited times.

Restriction: Upper-division students only.

CBEMS 199. Individual Study. 1-4 Units.
For undergraduate engineering majors in supervised but independent readings, research, or design. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in the School of Engineering.

(Design units: 1-4)

Repeatability: May be taken for credit for 8 units.

Restriction: Chemical Engineering Majors have first consideration for enrollment. Materials Science Engineering Majors have first consideration for enrollment.

CBEMS 199P. Individual Study. 1-4 Units.
For undergraduate Engineering majors in supervised but independent reading, research, or design. Students taking individual study for design credit are to submit a written paper to the instructor and to the Undergraduate Student Affairs Office in The School of Engineering.

(Design units: 1-4)

Grading Option: Pass/no pass only.

Repeatability: May be repeated for credit unlimited times.

CBEMS 210. Reaction Engineering. 4 Units.
Advanced topics in reaction engineering, reactor stability analysis, diffusional effect in heterogeneous catalysis, energy balance, optimization of reactor operation, dispersed in phase reactors.

Restriction: Graduate students only.
CBEMS 215. Kinetics of Biochemical Networks. 4 Units.
Principles from statistical mechanics, thermodynamics, and chemical kinetics applied to biochemical systems, from fundamental processes such as receptor-ligand binding and enzyme catalysis, to complex cellular functions including signal transduction and gene regulation.

Restriction: Graduate students only.

Concurrent with CBEMS 115.

CBEMS 218. Bioengineering with Recombinant Microorganisms. 4 Units.
Engineering and biological principles important in recombinant cell technology. Host/vector selection; plasmid propagation; optimization of cloned gene expression; metabolic engineering; protein secretion; experimental techniques; modeling of recombinant cell systems.

Restriction: Graduate students only.

CBEMS 219. Biomaterials: Structural Biology and Assembly. 4 Units.
Application of fundamental concepts in structural biology (proteins, DNA/RNA, carbohydrates, lipids), biomolecular thermodynamics, and molecular interactions to the design of novel biomaterials via self-assembly.

Concurrent with CBEMS 119.

CBEMS 220. Transport Phenomena. 4 Units.
Heat, mass, and momentum transfer theory from the viewpoint of the basic transport equations. Steady and unsteady state; laminar and turbulent flow; boundary layer theory, mechanics of turbulent transport with specific application to complex chemical engineering situations.

Restriction: Graduate students only.

CBEMS 221. Drug Delivery. 4 Units.
Introduction to design of drug delivery systems. Includes physicochemical and pharmacokinetic considerations in drug formulations, types of therapeutics, routes of administration, biomaterials, and novel drug delivery systems.

CBEMS 228. Colloid Science and Engineering. 4 Units.
An introduction to the basic foundations of colloid science, interfacial phenomena, suspensions and complex fluids, and engineering and assembly of colloidal materials.

Restriction: Graduate students only.

Analytical techniques applied to engineering problems in transport phenomena, process dynamics and control, and thermodynamics.

Restriction: Graduate students only.

CBEMS 232. Bioseparation Processes. 4 Units.
Recovery and purification of biologically produced proteins and chemicals. Basic principles and engineering design of various separation processes including chromatography, electrophoresis, extraction, crystallization, and membrane separation.

Restriction: Graduate students only.

CBEMS 233. Nuclear and Radiochemistry. 4 Units.
Advanced treatment of nuclear structure, nuclear reactions, and radioactive-decay processes. Introduction to nuclear activation analysis, isotope effects, radiation chemistry, hot-atom chemistry, nuclear age-dating methods, nuclear reactors, and nuclear power.

Same as CHEM 233.

Restriction: Graduate students only.

Concurrent with CBEMS 133 and CHEM 133.

CBEMS 240. Advanced Engineering Thermodynamics. 4 Units.
Introduction to modern thermodynamics and applications, with a focus on aspects relevant to chemical and materials engineering. Mathematical tools; equilibrium and stability; microscopic rigorous equations of state; molecular-level thermodynamics of real mixtures; and phase and chemical equilibrium.

Restriction: Graduate students only.
CBEMS 241. Nano-Scale Materials and Applications. 4 Units.
Overview of the chemistry, physics, and applications of nanometer-scale materials. Explore the effects of composition, bonding, and confinement on physical properties of nanomaterials, their chemical syntheses, and their device physics in electronic, optoelectronic, and energy technologies.

Restriction: Graduate students only.

Concurrent with CBEMS 141.

CBEMS 242A. Physical and Geometrical Optics. 4 Units.
Focuses on the practical aspects of optics and optical engineering, starting at the fundamentals. Topics include geometrical optics, ray tracing, polarization optics, interferometers, and diffractive optics.

Same as CHEM 242A.

Restriction: Graduate students only.

Concurrent with PHYSICS 134A.

CBEMS 242B. Applied Optics. 4 Units.
Focuses on the treatment of a wide variety of tools and techniques used in optics, particularly in research. Subjects include an introduction to lasers, optical detection, coherent optics, spectroscopic techniques, and selected topics corresponding to the interest of the students.

Prerequisite: CHEM 242A

Same as CHEM 242B.

CBEMS 243. Chemistry and Technology for the Nuclear Fuel Cycle. 4 Units.
Introduces basic concepts of nuclear chemistry and focuses on chemical engineering aspects of the nuclear power industry. A broad survey of the nuclear fuel cycle (uranium processing, reactor concepts, spent fuel treatment and repositories) will be given.

Restriction: Graduate students only.

Concurrent with CBEMS 143.

CBEMS 244. Detection and Measurement of Radiation. 4 Units.
Basic principles of detection and measurement of ionizing radiation; both theory and practical aspects of measurement techniques for alpha, beta, gamma, and neutron radiation, properties of different detector materials, electronics and data treatments, and analysis.

Prerequisite: CHEM 233 or CBEMS 233

Same as CHEM 244.

Restriction: Graduate students only.

CBEMS 249. Special Topics in Chemical Engineering and Materials Science. 1-4 Units.
Studies in selected areas of Chemical Engineering and Materials Science. Topics addressed vary each quarter.

Prerequisite: Prerequisites vary.

Repeatability: Unlimited as topics vary.

Restriction: Graduate students only.

CBEMS 280. Optoelectronics Packaging. 4 Units.
Basic and current issues in the packaging of integrated circuits (IC) and fiber-optic devices are discussed.

Restriction: Graduate students only.

CBEMS 295. Seminars in Engineering. 1-4 Units.
Seminars scheduled each year by individual faculty in major field of interest.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: Unlimited as topics vary.

Restriction: Graduate students only.
CBEMS 296. Master of Science Thesis Research. 1-16 Units.
Individual research or investigation conducted in preparation for the thesis required for the M.S. degree.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

CBEMS 297. Doctor of Philosophy Dissertation Research. 1-16 Units.
Individual research or investigation conducted in preparation for the dissertation required for the Ph.D. degree.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

CBEMS 298. Seminars in Engineering. 2 Units.
Presentation of advanced topics and reports of current research efforts in chemical engineering and materials science.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

CBEMS 299. Individual Research. 1-16 Units.
Individual research or investigation under the direction of an individual faculty member.

Grading Option: Satisfactory/unsatisfactory only.

Repeatability: May be repeated for credit unlimited times.

Restriction: Graduate students only.

Chem Engr and Materials Sci Courses

Principles and concepts underlying the study of advanced materials including alloys, composites, ceramics, semiconductors, polymers, ferroelectrics, and magnetics. Crystal structure and defects, surface and interface properties, thermodynamics and kinetics of phase transformations, and material processing, related to fundamental material properties.

Restriction: Graduate students only.

ENGRMSE 205. Materials Physics. 4 Units.
Covers the electronic, optical, and dielectric properties of crystalline materials to provide a foundation of the underlying physical principles of governing the properties of existing and emerging electronic and photonic materials.

Restriction: Graduate students only.

ENGRMSE 251. Dislocation Theory. 4 Units.
Theory of elasticity and symmetry of crystals, plasticity and slip systems, stress field of dislocation, dislocation reaction, theories of yielding and strengthening, application of reaction-rate kinetics to thermally activated dislocation motion.

Restriction: Graduate students only.

ENGRMSE 252. Theory of Diffusion. 4 Units.

Restriction: Graduate students only.

ENGRMSE 254. Polymer Science and Engineering. 4 Units.
An introduction to physical aspects of polymers, including configuration and conformation of polymer chains and characterization techniques; crystallinity viscoelasticity, rheology and processing.

Restriction: Graduate students only.

Concurrent with CBEMS 154.
ENGRMSE 255A. Design with Ceramic Materials. 4 Units.

Prerequisite: ENGR 54
Restriction: Graduate students only.

ENGRMSE 255A. Mechanical Behavior of Engineering Materials. 4 Units.
Principles governing structure and mechanical behavior of materials, relationship relating microstructure and mechanical response with application to elasticity, plasticity, creep, and fatigue, study of rate-controlling mechanisms and failure modes, fracture of materials.

Restriction: Graduate students only.

ENGRMSE 256A. Fracture of Engineering Materials. 4 Units.
Fracture mechanics and its application to engineering materials. Elastic properties of cracks, the stress intensity factor, the crack tip plastic zone, the J integral approach, fracture toughness testing, the crack tip opening displacement, fracture at high temperatures, fatigue crack growth.

Restriction: Graduate students only.

ENGRMSE 256B. Transmission Electron Microscopy. 4 Units.
The theory and operation of the transmission electron microscope (TEM), including the basic construction, electron optics, electron diffraction and reciprocal space, formation of image and electron diffraction information, microanalysis, and specimen preparation.

Prerequisite: ENGRMSE 200
Restriction: Graduate students only.

ENGRMSE 261. High Temperature Deformation of Engineering Materials. 4 Units.
Theoretical and practical aspects of creep and superplasticity in metallic and non-metallic systems are presented. Topics include: creep testing methods, diffusional creep, deformation mechanism maps, and superplasticity in non-metallics.

Restriction: Graduate students only.

ENGRMSE 262. Grain Boundaries & Interfaces in Nanocrystalline Materials. 4 Units.
Structure and character of grain boundaries and interfaces in solids including nanocrystalline materials. Role of grain boundaries in chemical segregation, fracture, deformation, creep, conductivity, diffusion, and grain growth. Experimental techniques and computational methods used to characterize and model grain boundaries.

Prerequisite: ENGRMSE 200

ENGRMSE 263. Computer Techniques in Experimental Research. 4 Units.
Principles and practical guidelines of automated materials testing. Computer fundamentals, programming languages, data acquisition and control hardware, interfacing techniques, programming strategies, data analysis, data storage, safeguard procedures.

Restriction: Graduate students only.

Concurrent with CBEMS 163.

ENGRMSE 264. Scanning Electron Microscopy. 4 Units.
The theory and operation of the scanning electron microscope (SEM) and X-ray microanalysis. Topics covered include the basic design and electron optics, electron beam - specimen interactions, image formation and interpretation, X-ray spectrometry, and other related topics and techniques.

Prerequisite: ENGRMSE 200
Restriction: Graduate students only.

ENGRMSE 265. Phase Transformations. 4 Units.
Advanced thermodynamics and kinetics of phase transformations and phase transitions.

Prerequisite: CBEMS 240
Restriction: Graduate students only.
ENGRMSE 268. Principles of Coatings, Thin Films, and Multi-layers. 4 Units.
Principles and concepts underlying the engineering of coating systems, thin films, and multilayers. Microstructure control, processing approaches, mechanical behavior, and thermomechanical characteristics and characterization. Interfacial stability, cracking, delamination, and thermal stress issues. Control of functional properties.

Restriction: Graduate students only.

ENGRMSE 273. Electroceramics & Solid State Electrochemical Systems. 4 Units.
Theory, underlying principles, experimental techniques, and applications of electroceramics and solid-state electrochemical systems. Links solid state physics, atomic structure, thermodynamics, defect chemistry, and transport processes to electrical properties of ceramics - spanning from insulators to fast-ion conductors and HT superconductors.

Prerequisite: ENGRMSE 200