Department of Chemical Engineering and Materials Science

916F Engineering Tower; (949) 824-3887
http://www.eng.uci.edu/dept/chems
Albert Yee, Department Chair

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

- Chemical Engineering
- Materials Science Engineering

Undergraduate Major in Chemical Engineering

Program Educational Objectives: Graduates of the Chemical Engineering program will (1) demonstrate a broad knowledge in the field of chemical engineering; (2) demonstrate critical reasoning and the requisite quantitative skills in seeking solutions to chemical engineering problems; (3) demonstrate skills for effective communication and teamwork; (4) effectively lead chemical engineering projects in industry, government, or academia; (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


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), 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 course work 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. Degree in Chemical Engineering

All students are required to meet the University Requirements (catalogue.uci.edu/previouseditions/2013-14/informationforadmittedstudents/requirementsforabachelorsdegree).

All students are required to meet the School Requirements (catalogue.uci.edu/previouseditions/2013-14/thehenrysamuelischoolofengineering/#undergraduatetext).

Major Requirements

Mathematics and Basic Science Courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<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>
</tr>
<tr>
<td>MATH 3D</td>
<td>Elementary Differential Equations</td>
</tr>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</td>
</tr>
<tr>
<td>CHEM 1A-1B-1C-1LD</td>
<td>General Chemistry and General Chemistry</td>
</tr>
<tr>
<td>CHEM 51A-51B-51C-51LB</td>
<td>Organic Chemistry and Organic Chemistry</td>
</tr>
<tr>
<td>or</td>
<td>Honors Organic Chemistry and Honors Organic Chemistry</td>
</tr>
<tr>
<td>CHEM H52A-H52B-H52C-H52LB</td>
<td>Honors Organic Chemistry and Honors Organic Chemistry</td>
</tr>
<tr>
<td>or</td>
<td>Honors Organic Chemistry Laboratory and Honors Organic Chemistry Laboratory</td>
</tr>
<tr>
<td>CHEM 131A-131B</td>
<td>Quantum Principles and Molecular Structure and Elementary Statistical Mechanics</td>
</tr>
<tr>
<td>PHYSICS 7C-7LC</td>
<td>Classical Physics and Classical Physics Laboratory</td>
</tr>
<tr>
<td>PHYSICS 7D-7LD</td>
<td>Classical Physics and Classical Physics Laboratory</td>
</tr>
</tbody>
</table>

Engineering Topics Courses:

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

ENGRMAE 10 Introduction to Engineering Computations
or EECS 10
ENGR 54
CBEMS 45A-45B-45C
CBEMS 110
CBEMS 125A-125B-125C
CBEMS 130
CBEMS 135
CBEMS 140A-140B
CBEMS 149A-149B

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)
and select the remaining units from the following:
- ENGRCEE 162 Introduction to Environmental Chemistry
- ENGRCEE 163 Biological 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:
- ENGR 150 Mechanics of Structures
- CBEMS 154 Polymer Science and Engineering
- CBEMS 155 Mechanical Behavior and Design Principles
- CBEMS 157 Composite Materials Design
- CBEMS 158 Ceramic Materials
- CBEMS 163 Computer Techniques in Experimental Materials Research
- CBEMS 174 Semiconductor Device Packaging
- CBEMS 175 Design Failure Investigation
- CBEMS 191 Materials Outreach
- CBEMS 199 Individual Study (up to 4 units; or CBEMS H199, up to 4 units)
- 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

<table>
<thead>
<tr>
<th>Freshman</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
<td></td>
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<tr>
<td>CHEM 1A</td>
<td>PHYSICS 7C</td>
<td>PHYSICS 7D</td>
<td></td>
</tr>
<tr>
<td>EECS 10 or ENGRMAE 10</td>
<td>PHYSICS 7LC</td>
<td>PHYSICS 7LD</td>
<td></td>
</tr>
<tr>
<td>General Education</td>
<td>CHEM 1B</td>
<td>CHEM 1C</td>
<td></td>
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<tr>
<td></td>
<td>General Education</td>
<td>CHEM 1LC</td>
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</table>

<table>
<thead>
<tr>
<th>Sophomore</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 3A</td>
<td>MATH 3D</td>
<td>MATH 2E</td>
<td></td>
</tr>
<tr>
<td>CHEM 51A</td>
<td>CHEM 51B</td>
<td>CHEM 51C</td>
<td></td>
</tr>
<tr>
<td>CHEM 1LD</td>
<td>CHEM 51LB</td>
<td>CHEM 51LC</td>
<td></td>
</tr>
<tr>
<td>CBEMS 45A</td>
<td>CBEMS 45B</td>
<td>CBEMS 45C</td>
<td></td>
</tr>
<tr>
<td>General Education</td>
<td>ENGR 54</td>
<td>General Education</td>
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<table>
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<tr>
<th>Junior</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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</thead>
<tbody>
<tr>
<td>CBEMS 110</td>
<td>CHEM 131B</td>
<td>CBEMS 125C</td>
<td></td>
</tr>
<tr>
<td>CBEMS 125A</td>
<td>CBEMS 125B</td>
<td>Technical Elective</td>
<td></td>
</tr>
<tr>
<td>CHEM 131A</td>
<td>CBEMS 130</td>
<td>Technical Elective</td>
<td></td>
</tr>
<tr>
<td>General Education</td>
<td>General Education</td>
<td>General Education</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Senior</th>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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</thead>
<tbody>
<tr>
<td>CBEMS 135</td>
<td>CBEMS 140B</td>
<td>CBEMS 149B</td>
<td></td>
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<tr>
<td>CBEMS 140A</td>
<td>CBEMS 149A</td>
<td>Technical Elective</td>
<td></td>
</tr>
<tr>
<td>ENGR 190W</td>
<td>Technical Elective</td>
<td>Technical Elective</td>
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<tr>
<td>Technical Elective</td>
<td>General Education</td>
<td>General Education</td>
<td></td>
</tr>
</tbody>
</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.

(Numero 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 super-conductivity, 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


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), 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 course work 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. Degree in Materials Science Engineering

All students must meet the University Requirements (catalogue.uci.edu/previouseditions/2013-14/informationforadmittedstudents/requirementsforabachelorsdegree). All students must meet the School Requirements of their Engineering major and the MSE major.

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.

Major Requirements

Mathematics and Basic Science Courses:

Core Courses:

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

**Basic Engineering or Science Elective Courses:**
Select one of the following:

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

**Engineering Topics Courses:**
Students must complete a minimum of 22 units of engineering design.

**Core Courses:**

- ENGRMAE 10  Introduction to Engineering Computations
- ENGRMAE 30  Statics
- or ENGR 30  Statics
- or ENGRCEE 30  Statics
- CBEMS 45B- 45C  Chemical Processing and Energy Balances and Chemical Engineering Thermodynamics
- or ENGRMAE 91  Introduction to Thermodynamics
- CBEMS 50L  Principles of Materials Science and Engineering
- CBEMS 125A  Momentum Transfer
- or ENGRMAE 130A  Introduction to Fluid Mechanics
- CBEMS 125B  Heat Transfer
- or ENGRMAE 120  Heat and Mass Transfer
- CBEMS 155  Mechanical Behavior and Design Principles
- CBEMS 155L  Mechanical Behavior Laboratory
- CBEMS 160  Advanced Laboratory in Chemistry and Synthesis of Materials
- CBEMS 164  X-ray Diffraction, Electron Microscopy, and Microanalysis
- CBEMS 165  Diffusion and Phase Transformations
- CBEMS 169  Electronic and Optical Properties in Materials
- CBEMS 175  Design Failure Investigation
- CBEMS 189A- 189B- 189C  Senior Design Project and Senior Design Project and Senior Design Project
- CBEMS 190  Materials Selection and Design
- ENGR 54  Principles of Materials Science and Engineering
- ENGR 150  Mechanics of Structures
- ENGRMAE 150L  Mechanics of Structures Laboratory
- EECS 70A  Network Analysis I

**Engineering Electives:**
Students must complete a minimum of 19 units from:

- BME 50A  Cell and Molecular Engineering
- BME 110A- 110B  Biomechanics I and Biomechanics II
- BME 111  Design of Biomaterials
- BME 120  Quantitative Physiology: Sensory Motor Systems
- CBEMS 110  Reaction Kinetics and Reactor Design
- CBEMS 130  Separation Processes
- CBEMS 154  Polymer Science and Engineering
- CBEMS 157  Composite Materials Design
- CBEMS 158  Ceramic Materials
- CBEMS 163  Computer Techniques in Experimental Materials Research
- CBEMS 174  Semiconductor Device Packaging
- CBEMS 191  Materials Outreach
- CBEMS 199  Individual Study
- EECS 70B  Network Analysis II
- EECS 170LA  Electronics I Laboratory
- EECS 170B  Electronics II
- EECS 174  Semiconductor Devices
- EECS 176  Fundamentals of Solid-State Electronics and Materials
- EECS 180A  Engineering Electromagnetics I
- ENGR 165  Advanced Manufacturing
- 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

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:**

- ENGR 190W  Communications in the Professional World
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

**Freshman**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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<tbody>
<tr>
<td>MATH 2A</td>
<td>MATH 2B</td>
<td>MATH 2D</td>
</tr>
<tr>
<td>CHEM 1A</td>
<td>CHEM 1B</td>
<td>PHYSICS 7D</td>
</tr>
<tr>
<td>ENGRMAE 10</td>
<td>CHEM 1LE</td>
<td>PHYSICS 7LD</td>
</tr>
<tr>
<td>General Education</td>
<td>PHYSICS 7C</td>
<td>CHEM 1C</td>
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</tbody>
</table>

**Sophomore**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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<tbody>
<tr>
<td>MATH 3A</td>
<td>MATH 3D</td>
<td>MATH 2E</td>
</tr>
<tr>
<td>PHYSICS 7E</td>
<td>ENGR 54</td>
<td>CBEMS 50L</td>
</tr>
<tr>
<td>ENGR 30</td>
<td>CBEMS 45B</td>
<td>CBEMS 45C</td>
</tr>
<tr>
<td>General Education</td>
<td>Basic Engineering/Science Elective</td>
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**Junior**

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<tr>
<th>Fall</th>
<th>Winter</th>
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<tbody>
<tr>
<td>ENGR 150</td>
<td>CBEMS 155</td>
<td>CBEMS 160</td>
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<tr>
<td>ENGRMAE 150L</td>
<td>CBEMS 155L</td>
<td>CBEMS 169</td>
</tr>
<tr>
<td>CBEMS 164 (includes lab)</td>
<td>CBEMS 125B</td>
<td>CBEMS 165</td>
</tr>
<tr>
<td>CBEMS 125A</td>
<td>EECS 70A</td>
<td>General Education</td>
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<tr>
<td>General Education</td>
<td>General Education</td>
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</table>

**Senior**

<table>
<thead>
<tr>
<th>Fall</th>
<th>Winter</th>
<th>Spring</th>
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<tbody>
<tr>
<td>CBEMS 189A</td>
<td>CBEMS 189B</td>
<td>CBEMS 189C</td>
</tr>
<tr>
<td>ENGR 190W</td>
<td>CBEMS 190</td>
<td>Engineering Elective</td>
</tr>
<tr>
<td>Engineering Elective</td>
<td>CBEMS 175</td>
<td>Engineering Elective</td>
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<tr>
<td>General Education</td>
<td>Engineering Elective</td>
<td>General Education</td>
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</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>CHEM 1A</th>
<th>General Chemistry</th>
</tr>
</thead>
<tbody>
<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 3A</td>
<td>Introduction to Linear Algebra</td>
</tr>
<tr>
<td>MATH 2E</td>
<td>Multivariable Calculus</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>
</tbody>
</table>
 PHYSICS 7D  Classical Physics
 PHYSICS 7LD  Classical Physics Laboratory

Requirements

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

Required courses:
ENGR 54  Principles of Materials Science and Engineering
CBEMS 155  Mechanical Behavior and Design Principles

Select three of the following:
CBEMS 165  Diffusion and Phase Transformations
CBEMS 169  Electronic and Optical Properties in Materials
CBEMS 175  Design Failure Investigation
CBEMS 199  Individual Study (contingent upon the availability of research positions in the Materials Science Engineering faculty’s research groups)

Electives:
Select two of the following:
ENGR 150  Mechanics of Structures
CBEMS 154  Polymer Science and Engineering
CBEMS 157  Composite Materials Design
CBEMS 158  Ceramic Materials
CBEMS 163  Computer Techniques in Experimental Materials Research
CBEMS 174  Semiconductor Device Packaging
CBEMS 191  Materials Outreach
EECS 170A- 170B  Electronics I and Electronics II
BME 110A- 110B  Biomechanics I and Biomechanics II
BME 111  Design of Biomaterials
BME 120  Quantitative Physiology: Sensory Motor Systems
ENGR 165 Advanced Manufacturing
ENGRMAE 151  Mechanical Engineering Design
ENGRMAE 155  Composite Materials and Structures
ENGRMAE 157  Lightweight Structures
CHEM 130A  Chemical Thermodynamics
CHEM 225  Polymer Chemistry: Synthesis and Characterization of Polymers
MATH 112A  Introduction to Partial Differential Equations and Applications
or ENGRMAE 140  Introduction to Engineering Analysis
PHYSICS 112A  Electromagnetic Theory
PHYSICS 133  Introduction to Condensed Matter Physics
PHYSICS 135  Introduction to Plasma Physics

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.

• 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. degrees 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. degree and as a basis for the Ph.D. preliminary examination.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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<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>
</tbody>
</table>
Electives
Graduate 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.

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. degree.

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. degree. The following are required: four required core courses, three quarters of CBEMS 298 (Department Seminar), three additional Chemical Engineering-related graduate elective courses numbered 200–289 approved by the graduate advisor, and two additional non-Chemical Engineering-related graduate elective courses numbered 200–289 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 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 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), three additional Chemical Engineering-related graduate elective courses numbered 200–289 approved by the graduate advisor, and two additional non-Chemical Engineering-related graduate elective courses numbered 200–289 approved by the graduate advisor. Up to two of the elective courses may be substituted by upper-division undergraduate elective courses if these courses are approved by the CBE graduate advisor.

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

NOTE: Students who entered prior to fall 2012 should follow the course requirements outlined within the Catalogue of the year they entered. The change in number of units per course is not intended to change the course requirements for the degree nor to have any impact in the number of courses students are taking. As such, students will need to continue to meet the same high standards and plan of study requirements as previously required. Students will work with their advisor to create a plan of study encompassing the equivalent topical requirements, as well as the equivalent number of courses to the previous 36-unit requirement.

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. degree 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. degree are the same as for the M.S. degree. Students must enroll in the departmental seminar each quarter unless exempt by petition. Ph.D. students must take two additional elective courses beyond the M.S. degree 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. degree 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 reapply to the Ph.D. program after completing the M.S. degree. Students who apply to the M.S./only program must formally apply 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. degree 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:

Select one of the following:

- ENGRMSE 252 Theory of Diffusion
- 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. degree 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. degree.

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 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 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 200–289 approved by the graduate advisor. Up to two of these elective courses may be substituted by upper-division undergraduate elective courses if these courses are approved by the MSE graduate advisor.

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

NOTE: Students who entered prior to fall of 2012 should follow the course requirements outlined within the Catalogue of the year they entered. The change in number of units per course is not intended to change the course requirements for the degree nor to have any impact in the number of courses students are taking. As such, students will need to continue to meet the same high standards and plan of study requirements as previously required. Students will work with their advisor to create a plan of study encompassing the equivalent topical requirements, as well as the equivalent number of courses to the previous 36-unit requirement.

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The Ph.D. degree 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 unless exempt by petition. Ph.D. students must take two additional elective courses beyond the M.S degree 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. degree 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. degree 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.

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**Faculty**

Nancy A. Da Silva: Molecular biotechnology, metabolic engineering, environmental biotechnology

James C. Earthman: Fatigue behavior and cyclic damage, automated materials testing and diagnostics, high-temperature fracture, biomaterials, green materials

Alon A. Gorodetsky: Biomolecular electronics, organic solar cells, nanotechnology, DNA, materials chemistry

Allon Hochbaum: Nanoscale materials and hybrid bio-inorganic devices for applications in clean energy

Martha L. Mecartney: Grain boundary engineering of ceramics, superplastic ceramics, solid oxide fuel cell materials, ceramics for nuclear waste storage

Farghalli A. Mohamed (*Emeritus*): Mechanical properties, creep, superplasticity, correlations between properties of materials and their microstructure, mechanical behavior at the nanoscale

Ali Mohraz: Guided and self assembly of colloids, soft matter physics, microstructured materials synthesis for energy and biomimetic application, colloids for environmental remediation

Daniel R. Mumma: Enabling materials for energy systems and propulsion (solid oxide fuel cells, thermal barrier coatings), interface mechanics, materials behavior at high temperature, lightweight/multi-functional structures, nanostructured materials, electron microscopy and microanalysis

Hung D. Nguyen: Thermodynamic computer simulations, nanoscale self-assembly, virus assembly, protein folding/aggregation

Mikael Nilsson: Advanced nuclear fuel cycles, actinide chemistry, liquid-liquid extraction, process development, radiolysis, detection and detectors for online process control

Regina Ragan: Self-assembly of hybrid organic/inorganic nanostructures for nanoelectronic and sensing applications; correlating electron transport and optical properties with atomic and molecular structure

Elizabeth L. Read: Dynamics of complex biochemical systems, regulation of immune responses

Frank G. Shi: Materials packaging/manufacturing technologies for optoelectronic devices (LEDs, solar cells, sensors, etc.); polymer nanocomposites; die attach adhesives and electrical/thermal conductive pastes; silicone and epoxy encapsulants; luminescent and phosphor materials; optical glass

Vasan Venugopalan: Application of laser radiation for medical diagnostics, therapeutics and biotechnology; laser-induced thermal, mechanical, and radiative transport processes

Szu-Wen Wang: Biomolecular engineering, interfacial engineering, nanostructured biomaterials, drug delivery

Albert Yee: Nanofabrication of soft materials, physics of polymer thin films, nanomechanical properties of polymers, ultra-low-k dielectrics, fracture and toughening of polymer nanocomposites

**Affiliated Faculty**

James P. Brody: Bioinformatics, micro-nanoscale systems

Peter J. Burke: Nano-electronics, bio-nanotechnology

Zhongping Chen: Biomedical optics, optical coherence tomography, bioMEMS, and biomedical devices

William J. Cooper: Environmental chemistry, advanced oxidation processes for water treatment, aquatic photochemistry of carbon cycling

Aaron P. Esser-Kahn: Polymer chemistry, microvascular materials, immune programming

Steven C. George: Physiological and multi-scale integrative modeling, gas exchange, computational methods, tissue engineering

Stanley B. Grant: Environmental engineering, inland and coastal water quality, coagulation and filtration of colloidal contaminants, environmental microbiology
Anna Grosberg: Computational modeling of biological systems, biomechanics, cardiac tissue engineering

Zhibin Guan: Materials, nanoscience, organic and polymer chemistry, and chemical biology

G. Wesley Hatfield: Molecular mechanisms of biological control systems

Michelle Khine: Development of novel nano- and micro-fabrication technologies and systems for single cell analysis, stem cell research, and in-vitro diagnostics

Young Jik Kwon: Gene therapy, drug delivery, cancer-targeted therapeutics, stem cell bioreactors, biomaterials, cell and tissue engineering, mathematical modeling

Matthew Law: Analytical, inorganic, materials, nanoscience, physical and polymer chemistry, and chemical physics

Guann-Pyng Li: High-speed semiconductor technology, optoelectronic devices, integrated circuit fabrication and testing

Wendy Liu: Biomaterials, microdevices in cardiovascular engineering, cell-cell and cell-micro-environment interactions, cell functions and controls

John S. Lowengrub: Mathematical materials science, mathematical fluid dynamics, mathematical biology, computational mathematics, cancer modeling, nanomaterials, quantum dots, complex fluids

Marc J. Madou: Fundamental aspects of micro/nano-electro-mechanical systems (MEMS/NEMS), biosensors, nanofluidics, biomimetics

Reginald Penner: Nanomaterials, chemical sensing, optoelectronics, energy conversion

Peter M. Rentzepis: Physical chemistry and picosecond spectroscopy

Diego Rosso: Environmental process engineering, mass transfer, wastewater treatment, carbon- and energy-footprint analysis

Timothy Rupert: Mechanical behavior, mechatronics, biomedical engineering, rehabilitation, biomechanics, neural control of movement

Suzanne B. Sandmeyer: Retroelements, metabolic molding, genomics

Kenneth J. Shea: Organic, polymer, and analytical chemistry

Lizhi Sun: Mechanics and materials, composites, micro- and nano-mechanics, elastography xdx

Lorenzo Valdevit: Multifunctional sandwich structures, thermal protection systems, morphing structures, active materials, MEMS, electronic packaging, cell mechanics

H. Kumar Wickramasinghe: Nanoscale measurements and characterization, scanning probe microscopy, storage technology, nanobio measurement technology

Affiliated faculty are from The Henry Samueli School of Engineering, the School of Medicine, and the School of Physical Sciences.

Chemical and Biochemical Engineering and Materials Science 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.

**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.

Overlaps with ENGRMAE 91.

Restriction: Chemical Engineering and 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.

Restriction: Chemical Engineering and 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.

(Design units: 0)

Corequisite: ENGR 54.

Restriction: Materials Science Engineering majors have first consideration for enrollment.
CBEMS 108. Biopharmaceutics & Nanomedicine. 4 Units.
Introduces theories and tools of new drug formulations. Particularly new novel therapeutics based on biological materials, pathological characteristics utilized to achieve the maximum efficacy and specificity, and drug delivery systems based on emerging nanotechnology are extensively discussed.
Prerequisite: PHRMSCI 170B
Same as PHRMSCI 174.
Restriction: Prerequisite required

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 45C with a grade of C- or better.
Restriction: Chemical Engineering, Mechanical Engineering, and 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 116. Field Practicum in Environmental Engineering. 4 Units.
Application of concepts from engineering and microbiology to the characterization and analysis of microbial pollution in coastal waters. Topics include public health microbiology, microbial diversity and ecology, and molecular diagnostics of waterborne pathogens. Laboratory exercises and a field-scale experiment.
(Design units: 2)
Corequisite: CBEMS 110 or ENGRCEE 162.
Restriction: Chemical Engineering majors have first consideration for enrollment.

Concurrent with CBEMS 216.

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 and Materials Science Engineering majors have first consideration for enrollment.

Concurrent with CBEMS 219.

CBEMS 124. Transport Phenomena in Living Systems. 3 Units.
An introduction to transport phenomena in cellular and whole organ systems. Application of transport theory including advection and diffusion to the movement of molecules in biological systems, including the cardiovascular system (heart and microcirculation), and the lung.
(Design units: 0)
Prerequisite: CBEMS 125A.
Restriction: Biomedical Engineering and Chemical Engineering majors have first consideration for enrollment.

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.
Prerequisite: CBEMS 45A and CBEMS 45B and CBEMS 45C and MATH 3D.
Overlaps with ENGRMAE 130A, ENGRCEE 170.
Restriction: Chemical Engineering and 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 with a grade of C- or better.
Overlaps with CBEMS 120B, ENGRMAE 120.
Restriction: Chemical Engineering and 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 and CBEMS 125A.

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

CBEMS 132. Bioseparation Processes. 3 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.

(Design units: 1)
Prerequisite: CBEMS 45A and CBEMS 45B and CBEMS 45C and CBEMS 125A.
Restriction: Chemical 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 170.
Concurrent with CBEMS 233.

CBEMS 134. Introduction to Bioreactor Engineering. 3 Units.
Unique features of bioreactors. Analyses and design of bioreactors of batch, fed-batch, and continuous flow types. Microbial reactors with and without cell recycles. Bioreactor operations for industrial-important biological products and for biological treatment of wastewater.

(Design units: 1.5)
Prerequisite: CBEMS 110.
Restriction: Chemical Engineering majors have first consideration for enrollment.

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.

(Design units: 1)
Prerequisite: CBEMS 110 and CBEMS 125C. CBEMS 110 with a grade of C- or better. CBEMS 125C with a grade of C- or better.
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.

(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: 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.
Overlaps with CBEMS 145.
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: CHEM 1A and CHEM 1B and CHEM 1C and ENGR 54.
Restriction: Chemical Engineering and Materials Science Engineering majors have first consideration for enrollment.

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, Materials Science Engineering, and 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.
Corequisite: CBEMS 155.
Prerequisite: ENGR 54.
Restriction: Materials Science Engineering majors have first consideration for enrollment.

CBEMS 157. Composite Materials Design. 3 Units.

(Design units: 3)
Prerequisite: ENGR 54 and ENGR 150.
Restriction: Chemical Engineering and 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 and Materials Science Engineering majors have first consideration for enrollment.

CBEMS 160. Advanced Laboratory in Chemistry and 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.

(Design units: 0)
Prerequisite: (CHEM 130A and CHEM 130B) or (CHEM 131A and CHEM 131B) or ENGR 54 or PHRMSCI 171.
Same as CHEM 156.
Restriction: Chemistry majors and Materials Science Engineering majors have first consideration for enrollment.

CBEMS 163. Computer Techniques in Experimental Materials 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 and Materials Science Engineering majors have first consideration for enrollment.
Concurrent with ENGRMSE 263.
CBEMS 164. X-ray Diffraction, Electron Microscopy, and Microanalysis. 4 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)
Prerequisite: CBEMS 50L and ENGR 54.
Restriction: Materials Science Engineering and Mechanical Engineering majors have first consideration for enrollment.

CBEMS 165. Diffusion and Phase Transformations. 3 Units.
Thermodynamics and kinetics of phase transformations, phase diagrams, diffusional and diffusionless transformations.

(Design units: 0)
Prerequisite: ENGR 54 and (ENGRMAE 91 or CBEMS 45C). ENGRMAE 91 with a grade of C- or better. CBEMS 45C 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 and 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: Prerequisite Chemical Engineering and Materials Science Engineering majors have first consideration for enrollment.

CBEMS 189A. Senior Design Project. 1 Unit.
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.

(Design units: 1)
Prerequisite: CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.
Grading Option: In progress only.
Restriction: Seniors only. Materials Science Engineering majors only.

CBEMS 189B. Senior Design Project. 2 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.

(Design units: 2)
Prerequisite: CBEMS 189A. CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.
Grading Option: In progress only.
Restriction: Seniors only. Materials Science Engineering majors only.

CBEMS 189C. Senior Design Project. 2 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.

(Design units: 2)
Prerequisite: CBEMS 189B. CBEMS 189A-CBEMS 189B-CBEMS 189C must be taken in the same academic year.
Restriction: Seniors only. Materials Science Engineering majors only.

CBEMS 190. Materials Selection and Design. 4 Units.

(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 and 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.

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 and 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.

Prerequisite: CBEMS 110.
Restriction: Graduate students only.

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.

Prerequisite: CBEMS 110 and CBEMS 112.
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.

Prerequisite: CBEMS 45C and CBEMS 110.
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.

Prerequisite: CBEMS 125A and CBEMS 125B and CBEMS 125C.

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.

Prerequisite: CHEM 1C and CBEMS 112 and (BME 50B or BIO SCI 93).

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.

Prerequisite: CBEMS 125A.
Restriction: Graduate students only.

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

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

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.

Prerequisite: CBEMS 112.
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.

Prerequisite: CHEM 170.
Same as CHEM 233.
Concurrent with CBEMS 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; microscope rigorous equations of state; molecular-level thermodynamics of real mixtures; and phase and chemical equilibrium.

Prerequisite: CBEMS 45B and CBEMS 45C.
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.

Prerequisite: CHEM 1A and MATH 2B and PHYSICS 7D.
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 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 250. 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 255. 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 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.
Materials Science Engineering 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.
Prerequisite: CHEM 1A and CHEM 1B and CHEM 1C and PHYSICS 7A and PHYSICS 7LA.
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.
Prerequisite: ENGR 54.
Restriction: Graduate students only.

ENGRMSE 252. Theory of Diffusion. 4 Units.
Prerequisite: ENGR 54.
Restriction: Graduate students only.

ENGRMSE 254. Polymer Science and Engineering. 4 Units.
An introduction to organic and physical chemistry polymers, including synthetic methods, reaction mechanisms; configuration and conformation of polymer chains and characterization techniques; viscoelasticity and rheology. Special topics in biopolymers and polymer surfaces.
Prerequisite: CBEMS 154.
Restriction: Graduate students only.

ENGRMSE 255A. Design with Ceramic Materials. 4 Units.
Prerequisite: ENGR 54.
Restriction: Graduate students only.

ENGRMSE 256A. 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.
Prerequisite: ENGR 54.
Restriction: Graduate students only.

ENGRMSE 256B. 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.
Prerequisite: CBEMS 155 or ENGRMAE 156.
Restriction: Graduate students only.

ENGRMSE 259. 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. Includes laboratory component.
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-metals.
Prerequisite: ENGR 54 and (CBEMS 155 or ENGRMAE 156).
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 Materials 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 165 or CBEMS 240.

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.

Prerequisite: ENGR 54.

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.