Molecular Engineering

Overview of Molecular Engineering

Engineering is the science of solving complex technological problems and, in the case of molecular engineering, using tools and concepts that arise from the fundamentals of science at the nanoscale. The Pritzker School of Molecular Engineering (PME) is at the forefront of emerging fields in engineering that have the potential to address fundamental problems of societal import and to translate basic discoveries into useful technologies. This exciting new field involves the incorporation of synthetic molecular building blocks into functional systems that will impact technologies in energy storage and harvesting, water purification and utilization, immunoengineering and advanced medical therapies, and quantum information and technology. Faculty in the Pritzker School of Molecular Engineering conduct research at the intersection of chemical, electrical, mechanical, and biological engineering, as well as the materials, biological, and physical sciences.

Program of Study in Molecular Engineering

The BS degree in Molecular Engineering offers undergraduates a cutting-edge engineering curriculum built on a strong foundation in mathematics, physics, chemistry, and biology. Majors choose from three quantitative engineering tracks: one track aimed at engineering with a biology emphasis, a track with a focus on chemical and soft materials, and a track geared toward quantum engineering.

Courses in the major are designed to develop quantitative reasoning and problem-solving skills; to introduce engineering analysis of biological, chemical, and physical systems; and to address open-ended technological questions across a spectrum of disciplines. The aim is to introduce invention and design, along with inquiry and discovery, as fruitful and complementary intellectual activities. The program both prepares undergraduates for a wide variety of careers in technology-focused industries and positions them for further postgraduate study in such fields as engineering, science, medicine, business, or law.

Major Program Requirements

1. A strong and broad background in mathematics, physics, chemistry, and biology. It is imperative for a modern engineer to have a strong and broad background in the sciences, and the highly interdisciplinary nature of molecular engineering requires a foundation built across the mathematical, physical, and biological sciences.

Completing mathematics, chemistry, and physics course work during the first year at the University of Chicago is necessary for students interested in taking advantage of specializations in Molecular Engineering (for example, in polymers and soft materials, sustainable energy and water resources, immunoengineering, or quantum information science), advanced electives, research and design projects, and other opportunities beyond the required major course work. Completion of at least MATH 15300, CHEM 11300, and PHYS 13300, or approved equivalents, by the end of the first year is a prerequisite for Molecular Engineering course work during a student’s second year. Therefore, all students majoring in Molecular Engineering who matriculate in 2019 or later are strongly advised to take mathematics, chemistry, and physics courses concurrently during their first year at the University. Students also are advised to start the mathematics, chemistry, and physics sequences at the highest level for which they are prepared, and to complete their general education requirements as early as possible. Students who satisfy the mathematics, chemistry, and physics requirements during their second year will be able to complete the Molecular Engineering major during their third and fourth years, but will be unable to avail themselves of the advanced engineering opportunities highlighted above.

2. Three Molecular Engineering tracks. Reflecting the research and education themes of the Pritzker School of Molecular Engineering, three distinct tracks for the major are available to students. One track is aimed at preparing students oriented towards biological engineering, another is aimed toward chemical and soft materials, and the third is aimed at preparing students for the engineering of quantum-based materials, devices, and processes.

3. Starting the program. Students begin the Molecular Engineering course work with enrollment in either MENG 26010 Engineering Principles of Conservation or MENG 26020 Engineering Electrodynamics. Both courses require the completion of their stated prerequisites. Students should plan with their College advisers early in their first year of study for those prerequisites to be completed in a timely manner.

Rising second-year students should plan on taking these courses in the Spring Quarter of 2020. Note that, beginning in the 2020–21 academic year, the timing of these first courses in Molecular Engineering will be shifted forward and offered starting in the Autumn Quarter. Therefore, students majoring in Molecular Engineering who matriculate in 2019 should plan to enroll in their first course in Molecular Engineering in the Autumn Quarter of 2020.

4. MENG 26030 Introduction to Engineering Analysis. One of the first courses for all Molecular Engineering majors, this course teaches students to apply mathematical methods towards solving problems that cut across multiple engineering subdisciplines. A major objective of the course is to teach simple programming skills and computational methods in applied mathematics, including the use of such engineering software as Python and Matlab. The skills that are introduced here will be applied and further developed throughout the rest of the curriculum.

5. MENG 29511-29512 Engineering Design I-II (200-unit capstone sequence). This design course is a two-quarter sequence that teaches students how to combine fundamental science and engineering to solve open-ended problems, for example, analyzing the chemical and biological properties of cancer cells to develop new treatment and delivery vehicles or
harnessing the properties of electrons in materials to develop quantum information technologies. Engineers from industry, the national laboratories, and academia, including PME faculty and fellows, will propose real-world projects for which they will serve as mentors. Students will work together in small teams throughout the two quarters to address the diverse engineering challenges that arise.

The design course also serves as a vehicle to teach other equally important non-technical skills, including:

- Problem identification: technology analysis, competitive analysis, market analysis, stakeholder analysis, product definition
- Impact of the project, including sociological and engineering ethics
- Project planning
- Project economics: costs, value/investment analysis, risk analysis and adjustment
- Prototyping, experimental design, data analysis, error analysis
- IP: patenting, prior art, patentability
- Legal and regulatory analysis
- Proposing, presenting, and reporting
- Teamwork

6. Advanced electives (four required courses in the major). The major is structured to allow for considerable flexibility for students to tailor their programs along individualized trajectories, with help from faculty advisers. Not only can students choose between multiple tracks, but they can further build breadth or depth through their choice of advanced electives. Moreover, we anticipate that our students will use elective courses outside of the major requirements to strengthen their backgrounds in specific areas of interest, also in consultation with Molecular Engineering advisers, to achieve desired outcomes such as preparation for graduate school in other engineering disciplines.

7. Laboratory skills and hands-on experience. Critical skills that molecular engineers must acquire as part of their educational program include the ability to apply knowledge of mathematics, science, and engineering and the ability to design and conduct experiments, as well as the ability to analyze and interpret data. Molecular Engineering majors develop these skills through lab components associated with required courses in the physical and biological sciences and Molecular Engineering courses including MENG 26101 Transport Phenomena I: Forces and Flows and MENG 26201-26202 Thermodynamics and Statistical Mechanics I-II. We also anticipate that many Molecular Engineering students will receive advanced laboratory experience pursuing undergraduate research projects.

8. Non-technical skills. Many decades of workshops and panels engaging stakeholders in academia and industry, often associated with the Accreditation Board for Engineering and Technology (ABET), have identified criteria for outcomes of students in engineering education programs. Although there is no plan to seek ABET accreditation for the Molecular Engineering major, many ABET criteria, particularly those related to non-technical skills, are achieved and viewed as essential to the Molecular Engineering major. Examples of student outcomes that fall into this category include: (a) an ability to formulate or design a system, process, or program to meet desired needs, (b) an ability to function on multidisciplinary teams, (c) an understanding of professional and ethical responsibility, (d) an ability to communicate effectively, (e) the broad education necessary to understand the impact of solutions in a global and societal context, (f) a recognition of the need for and an ability to engage in life-long learning, and (g) a knowledge of contemporary issues. Many of these outcomes will be addressed through both the Molecular Engineering degree curriculum (particularly emphasized in the design sequence) and the College general education requirements. Students who are able to both develop and articulate these skills will be positioned favorably for employment in industry and for postgraduate study in engineering, medicine, law, and business administration.

Summary of Requirements for the Major in Molecular Engineering: Biology Track

GENERAL EDUCATION

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 10100 &amp; CHEM 10200</td>
<td>Introductory General Chemistry I and Introductory General Chemistry II (or higher)</td>
<td>200</td>
</tr>
</tbody>
</table>

One of the following sequences: 200

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 13100-13200</td>
<td>Elementary Functions and Calculus I-II (requires a grade of A- or higher)</td>
</tr>
<tr>
<td>MATH 15100-15200</td>
<td>Calculus I-II</td>
</tr>
<tr>
<td>MATH 16100-16200</td>
<td>Honors Calculus I-II</td>
</tr>
</tbody>
</table>

One of the following sequences: 200

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOS 20186-20187</td>
<td>Fundamentals of Cell and Molecular Biology; Fundamentals of Genetics</td>
</tr>
<tr>
<td>BIOS 20234 &amp; BIOS 20235</td>
<td>Molecular Biology of the Cell and Biological Systems</td>
</tr>
</tbody>
</table>

Total Units 600

MAJOR

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 11300</td>
<td>Comprehensive General Chemistry III (or higher) 1</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 13100-13200-13300</td>
<td>Mechanics; Electricity and Magnetism; Waves, Optics, and Heat (or higher)</td>
<td>300</td>
</tr>
</tbody>
</table>
One of the following sets of three courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 13300</td>
<td>Elementary Functions and Calculus III OR MATH 15300 Calculus III OR MATH 16300 Honors Calculus III OR MATH 19620 Linear Algebra, AND MATH 20000-20100 Mathematical Methods for Physical Sciences I-II</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>MATH 16300 Honors Calculus III, AND MATH 20500 Analysis in Rn III OR MATH 20900 Honors Analysis in Rn III, AND MATH 27300 Basic Theory of Ordinary Differential Equations</td>
<td></td>
</tr>
</tbody>
</table>

MENG 26010 Engineering Principles of Conservation 100
MENG 26030 Introduction to Engineering Analysis 100
MENG 26101-26102 Transport Phenomena I: Forces + Flows; Transport Phenomena II 200
MENG 26201-26202 Thermodynamics and Statistical Mechanics I-II 200
MENG 29511-29512 Engineering Design I-II 200

Four advanced electives selected in consultation with the adviser for Molecular Engineering (at least two should be in the Biological Sciences above BIOS 20242). 5

Total Units 1900

1 Credit may be granted by examination.
2 Molecular Engineering majors can take these courses without the Biological Sciences prerequisites (BIOS 20150-20151) unless they pursue a double major in the Biological Sciences. They are expected to show competency in mathematical modeling of biological phenomena covered in BIOS 20151 Introduction to Quantitative Modeling in Biology (Basic).
3 Open only to students with a 4 or 5 on the AP Biology exam. Upon completion of BIOS 20234-20235-20236, students will be awarded a total of 200 units to be counted toward the general education requirement in the biological sciences.
4 MATH 13300 requires a grade of A- or higher.
5 Students should seek approval from the adviser for Molecular Engineering for their major electives before registering for and completing the courses.

Summary of Requirements for the Major in Molecular Engineering: Chemical and Soft Materials Track

GENERAL EDUCATION

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 10100</td>
<td>Introductory General Chemistry I</td>
<td>200</td>
</tr>
<tr>
<td>&amp; CHEM 10200</td>
<td>and Introductory General Chemistry II (or higher)</td>
<td></td>
</tr>
</tbody>
</table>

One of the following sequences:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 13100-13200</td>
<td>Elementary Functions and Calculus I-II (requires a grade of A- or higher)</td>
<td>200</td>
</tr>
<tr>
<td>MATH 15100-15200</td>
<td>Calculus I-II</td>
<td></td>
</tr>
<tr>
<td>MATH 16100-16200</td>
<td>Honors Calculus I-II</td>
<td></td>
</tr>
</tbody>
</table>

One of the following sequences:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOS 10602 &amp; BIOS 10603</td>
<td>Multiscale Modeling of Biological Systems I and Multiscale Modeling of Biological Systems II</td>
<td>200</td>
</tr>
<tr>
<td>BIOS 20186-20187</td>
<td>Fundamentals of Cell and Molecular Biology; Fundamentals of Genetics</td>
<td></td>
</tr>
<tr>
<td>BIOS 20234 &amp; BIOS 20235</td>
<td>Molecular Biology of the Cell and Biological Systems</td>
<td></td>
</tr>
</tbody>
</table>

Total Units 600

MAJOR

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 11300</td>
<td>Comprehensive General Chemistry III (or higher)</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 13100-13200-13300</td>
<td>Mechanics; Electricity and Magnetism; Waves, Optics, and Heat (or higher)</td>
<td>300</td>
</tr>
</tbody>
</table>

One of the following sets of three courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 13300 Elementary Functions and Calculus III OR MATH 15300 Calculus III OR MATH 16300 Honors Calculus III OR MATH 19620 Linear Algebra, AND MATH 20000-20100 Mathematical Methods for Physical Sciences I-II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td>MATH 16300 Honors Calculus III, AND MATH 20500 Analysis in Rn III OR MATH 20900 Honors Analysis in Rn III, AND MATH 27300 Basic Theory of Ordinary Differential Equations</td>
<td></td>
</tr>
</tbody>
</table>

MENG 26010 Engineering Principles of Conservation 100
MENG 26030 Introduction to Engineering Analysis 100
MENG 26101-26102 Transport Phenomena I: Forces + Flows; Transport Phenomena II 200
MENG 26201-26202 Thermodynamics and Statistical Mechanics I-II 200
### Summary of Requirements for the Major in Molecular Engineering: Quantum Track

#### GENERAL EDUCATION

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13100-13200</td>
<td>Mechanics; Electricity and Magnetism (or higher)</td>
<td>200</td>
</tr>
<tr>
<td>One of the following sequences:</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>MATH 13100-13200</td>
<td>Elementary Functions and Calculus I-II (requires a grade of A- or higher)</td>
<td></td>
</tr>
<tr>
<td>MATH 15100-15200</td>
<td>Calculus I-II</td>
<td></td>
</tr>
<tr>
<td>MATH 16100-16200</td>
<td>Honors Calculus I-II</td>
<td></td>
</tr>
<tr>
<td><strong>Total Units</strong></td>
<td></td>
<td><strong>400</strong></td>
</tr>
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</table>

#### MAJOR

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYS 13300</td>
<td>Waves, Optics, and Heat (or higher)</td>
<td>100</td>
</tr>
<tr>
<td>One of the following:</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>MATH 13300</td>
<td>Elementary Functions and Calculus III (requires a grade of A- or higher)</td>
<td></td>
</tr>
<tr>
<td>MATH 15300</td>
<td>Calculus III</td>
<td></td>
</tr>
<tr>
<td>MATH 16300</td>
<td>Honors Calculus III</td>
<td></td>
</tr>
<tr>
<td>PHYS 22000</td>
<td>Introduction to Mathematical Methods in Physics</td>
<td></td>
</tr>
<tr>
<td>CHEM 10100  &amp; CHEM 10200 &amp; CHEM 11300</td>
<td>Introductory General Chemistry I and Introductory General Chemistry II and Comprehensive General Chemistry III (or higher)</td>
<td>300</td>
</tr>
<tr>
<td>One of the following:</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>PHYS 22100</td>
<td>Mathematical Methods in Physics</td>
<td></td>
</tr>
<tr>
<td>MATH 20500</td>
<td>Analysis in Rn III</td>
<td></td>
</tr>
<tr>
<td>MATH 20900</td>
<td>Honors Analysis in Rn III</td>
<td></td>
</tr>
<tr>
<td>PHYS 15400</td>
<td>Modern Physics</td>
<td>100</td>
</tr>
<tr>
<td>PHYS 23400-23500</td>
<td>Quantum Mechanics I-II</td>
<td>200</td>
</tr>
<tr>
<td>MENG 26020</td>
<td>Engineering Electrodynamics</td>
<td>100</td>
</tr>
<tr>
<td>MENG 26030</td>
<td>Introduction to Engineering Analysis</td>
<td>100</td>
</tr>
<tr>
<td>One of the following sets of two courses:</td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>MENG 26201-26202</td>
<td>Thermodynamics and Statistical Mechanics I-II</td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 27900 Statistical and Thermal Physics, AND PHYS 23600 Solid State Physics OR PHYS 25000 Computational Physics OR CHEM 26300 Chemical Kinetics and Dynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEM 26200 Thermodynamics, AND PHYS 23600 Solid State Physics OR PHYS 25000 Computational Physics OR CHEM 26300 Chemical Kinetics and Dynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MENG 29511-29512</td>
<td>Engineering Design I-II</td>
<td>200</td>
</tr>
<tr>
<td>Four advanced electives from the list Approved Quantum Track Advanced Electives (below) or selected in consultation with the adviser for Molecular Engineering:</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td><strong>Total Units</strong></td>
<td></td>
<td><strong>1900</strong></td>
</tr>
</tbody>
</table>
Credit may be granted by examination; consult the adviser for Molecular Engineering.

Note: PHYS 27900 requires, and CHEM 26200 expects, prior experience with intermediate quantum mechanics; these options are well-suited to, but not exclusively for, students double-majoring in Physics or Chemistry.

Students should seek approval from the adviser for Molecular Engineering for their major electives before registering for and completing the courses.

Approved Quantum Track Advanced Electives

All 20000-level Molecular Engineering courses not otherwise required for the major (except those numbered MENG 20XXX and 29XXX)

All 20000-level Physics courses (except PHYS 29100-29200-29300 and PHYS 29700)

Courses in Mathematics and Statistics (no more than two to be used as program electives):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 20400</td>
<td>Analysis in Rn II</td>
</tr>
<tr>
<td>or MATH 20800</td>
<td>Honors Analysis in Rn II</td>
</tr>
<tr>
<td>MATH 20500</td>
<td>Analysis in Rn III (Neither MATH 20500 nor MATH 20900 can be counted toward electives if substituted for PHYS 22100.)</td>
</tr>
<tr>
<td>or MATH 20900</td>
<td>Honors Analysis in Rn III</td>
</tr>
<tr>
<td>MATH 27000</td>
<td>Basic Complex Variables</td>
</tr>
<tr>
<td>MATH 27200</td>
<td>Basic Functional Analysis</td>
</tr>
<tr>
<td>MATH 27300</td>
<td>Basic Theory of Ordinary Differential Equations</td>
</tr>
<tr>
<td>MATH 27400</td>
<td>Introduction to Differentiable Manifolds and Integration on Manifolds</td>
</tr>
<tr>
<td>MATH 27500</td>
<td>Basic Theory of Partial Differential Equations</td>
</tr>
<tr>
<td>STAT 23400</td>
<td>Statistical Models and Methods</td>
</tr>
<tr>
<td>or STAT 24400</td>
<td>Statistical Theory and Methods I</td>
</tr>
<tr>
<td>STAT 24500</td>
<td>Statistical Theory and Methods II</td>
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</table>

Other courses in the physical sciences:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM 26300</td>
<td>Chemical Kinetics and Dynamics</td>
</tr>
<tr>
<td>CHEM 26800</td>
<td>Computational Chemistry and Biology</td>
</tr>
<tr>
<td>CMSC 23710</td>
<td>Scientific Visualization</td>
</tr>
<tr>
<td>CMSC 28510</td>
<td>Introduction to Scientific Computing</td>
</tr>
<tr>
<td>GEOS 21200</td>
<td>Physics of the Earth</td>
</tr>
<tr>
<td>GEOS 23200</td>
<td>Climate Dynamics of the Earth and Other Planets</td>
</tr>
</tbody>
</table>

Courses in the biological sciences:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOS 29326</td>
<td>Introduction to Medical Physics and Medical Imaging</td>
</tr>
</tbody>
</table>

Courses not listed here can satisfy the advanced elective requirement if explicitly approved, on a case-by-case basis, by the adviser for Molecular Engineering.

Sample Major Programs

Below is a sample four-year program for the Chemical and Soft Materials Track. Students should rely on relevant placement tests and on the direction of the Molecular Engineering and College advisers in creating a personal four-year program that accommodates their individual backgrounds and interests. It is recommended that students complete the background mathematics, chemistry, and physics sequences during their first year at the University and start these sequences at the highest level for which they are prepared.

<table>
<thead>
<tr>
<th>First Year</th>
<th>Autumn Quarter</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 15100</td>
<td>MATH 15200</td>
<td>MATH 15300</td>
<td></td>
</tr>
<tr>
<td>CHEM 11100</td>
<td>CHEM 11200</td>
<td>CHEM 11300</td>
<td></td>
</tr>
<tr>
<td>PHYS 13100</td>
<td>PHYS 13200</td>
<td>PHYS 13300</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Second Year</th>
<th>Autumn Quarter</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 20000</td>
<td>MATH 20100</td>
<td>MATH 20200</td>
<td>BIOS 20186</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Third Year</th>
<th>Autumn Quarter</th>
<th>Winter Quarter</th>
<th>Spring Quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENG 26101</td>
<td>MENG 26102</td>
<td>MENG 26202</td>
<td></td>
</tr>
<tr>
<td>MENG 26030</td>
<td>MENG 26201</td>
<td>Advanced Elective</td>
<td></td>
</tr>
</tbody>
</table>
Below is a sample four-year program for the Quantum Track. Students should rely on relevant placement tests and on the direction of the Molecular Engineering and College advisers in creating a personal four-year program that accommodates their individual backgrounds and interests. It is recommended that students complete the background mathematics, chemistry, and physics sequences during their first year at the University and start these sequences at the highest level for which they are prepared.

First Year
- Autumn Quarter: MATH 15100
- Winter Quarter: MATH 15200
- Spring Quarter: MATH 15300
- CHEM 11100
- CHEM 11200
- CHEM 11300
- PHYS 14100
- PHYS 14200
- PHYS 14300

Second Year
- Autumn Quarter: PHYS 22100
- Winter Quarter: MENG 26020
- Spring Quarter: PHYS 15400
- PHYS 23400

Third Year
- Autumn Quarter: MENG 26030
- Winter Quarter: MENG 26201
- Spring Quarter: MENG 26202
- MENG 26010
- MENG 26202
- Advanced Elective

Fourth Year
- Autumn Quarter: MENG 29511
- Winter Quarter: MENG 29512
- Spring Quarter: Advanced Elective
- Advanced Elective

Minor Program in Molecular Engineering

The minor program in Molecular Engineering is designed for undergraduates majoring in the physical or biological sciences, mathematics, computer science, economics, or related fields. The overall objective of the program is to provide basic engineering tools and ways of thinking to students that augment scientific approaches and problem solving skills.

Minor Program Requirements

Before a student can declare the minor in Molecular Engineering, the student must complete the general education requirements in mathematics and physical sciences along with the course prerequisites for MENG 26010 Engineering Principles of Conservation. Following completion of all requirements, students must meet with the adviser for Molecular Engineering, Dr. Mark Stoykovich (stoykovich@uchicago.edu), to plan a course of study for the minor in the Molecular Engineering program. A student must then receive approval of the minor program on a Consent to Complete a Minor Program form (https://humanities-web.s3.us-east-2.amazonaws.com/college-prod/s3fs-public/documents/Consent_Minor_Program.pdf). The signed form must then be returned to the student's College adviser by the end of the Spring Quarter of the student's third year. Deviations from the course plan agreed upon in the Consent to Complete a Minor Program form require the approval of Dr. Stoykovich and submission of a revised Consent to Complete a Minor Program form prior to their implementation.

To earn the minor in Molecular Engineering, a student must complete six courses as outlined below. All courses in Molecular Engineering are pre-approved as advanced electives for the minor. Students should seek approval for all advanced electives that are outside of Molecular Engineering before enrolling in those courses. Before meeting with the adviser for Molecular Engineering, students should invest some thought into which courses they would like to complete for the minor and how those courses relate as a set.

Courses in the minor program may not be (1) double counted with the student's major(s) or with other minors, or (2) counted toward general education requirements. Courses in the minor must be taken for quality grades, and more than half of the requirements for the minor must be met by registering for courses bearing University of Chicago course numbers.

Summary of Requirements for the Minor in Molecular Engineering

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>MENG 26010</td>
<td>Engineering Principles of Conservation</td>
<td>100</td>
</tr>
<tr>
<td>MENG 26030</td>
<td>Introduction to Engineering Analysis</td>
<td>100</td>
</tr>
<tr>
<td>MENG 26201-26202</td>
<td>Thermodynamics and Statistical Mechanics I-II</td>
<td>200</td>
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<tr>
<td>OR</td>
<td></td>
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<tr>
<td>MENG 26101-26102</td>
<td>Transport Phenomena I: Forces + Flows; Transport Phenomena II</td>
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<td>OR</td>
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<tr>
<td>MENG 26101</td>
<td>Transport Phenomena I: Forces and Flows</td>
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<tr>
<td>AND</td>
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</tbody>
</table>
Molecular Engineering

**MENG 26201** Thermodynamics and Statistical Mechanics I

Two advanced electives selected in consultation with the PME adviser *

Total Units 600

* Students must secure approval before enrolling in courses they wish to use as advanced electives in the minor program.

**Minor Program in Molecular Engineering Technology and Innovation**

The overall objective of the minor program in Molecular Engineering Technology and Innovation is to introduce basic engineering concepts as they relate to evolving technologies, scientific innovation and entrepreneurship, scientific policy, and the broader impacts of engineering in society. The minor program is open to undergraduates from any major interested in these topics.

**Minor Program Requirements**

Students must complete the general education requirements in mathematics and physical sciences before declaring the minor in Molecular Engineering Technology and Innovation. Following completion of these requirements, students must meet with the adviser for Molecular Engineering, Dr. Mark Stoykovich (stoykovich@uchicago.edu), to plan a course of study for the minor. This meeting is mandatory and students who fail to have it may not be allowed to complete the minor. Prior to the meeting, students should invest some thought into which courses they would like to complete for the minor and how those courses relate as a set. The student and Dr. Stoykovich will fill out the Consent to Complete a Minor Program form [link](https://humanities-web.s3.us-east-2.amazonaws.com/college-prod/s3fs-public/documents/Consent_Minor_Program.pdf) jointly, and once the form is signed the student must bring it to the student's College adviser. Deviations from the course plan agreed upon in the Consent to Complete a Minor Program form require the approval of Dr. Stoykovich and submission of a revised Consent to Complete a Minor Program form prior to their implementation.

To earn the minor in Molecular Engineering Technology and Innovation, a student must complete six courses as outlined below. Advanced electives must be chosen in consultation with Dr. Stoykovich. All courses in Molecular Engineering are pre-approved as advanced electives for the minor.

Courses in the minor program may not be (1) double counted with the student's major(s) or with other minors, or (2) counted toward general education requirements. Courses in the minor must be taken for quality grades, and more than half of the requirements for the minor must be met by registering for courses bearing University of Chicago course numbers.

**Summary of Requirements for the Minor in Molecular Engineering Technology and Innovation**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>MENG 20000</td>
<td>Introduction to Emerging Technologies</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>2 to 5 additional courses in Molecular Engineering</td>
<td>200-500</td>
</tr>
<tr>
<td></td>
<td>0 to 3 elective courses selected in consultation with the PME adviser *</td>
<td>000-300</td>
</tr>
<tr>
<td>Total Units</td>
<td></td>
<td>600</td>
</tr>
</tbody>
</table>

* The following courses are pre-approved for the minor: BIOS 11140, BUSF 34103, BUSF 34106, BUSF 42703, ECON 22600, ECON 22650, ENST 23900, ENST 24705, ENST 26420, HIPS 17502, HIPS 21301, HIPS 25506, PBPL 21800, PBPL 23100, PBPL 24701, PBPL 29000, PHSC 12400, PHSC 12500. Students must secure approval before enrolling in courses that they wish to use as electives in the minor program and that are not on this pre-approved list.

**Grading**

In order to qualify for the BS degree, a GPA of 2.0 or higher (with no grade lower than C-) is needed in all courses required in the major. Students majoring in Molecular Engineering must receive quality grades in all courses required in the degree program. All courses in the minors must be taken for quality grades. Non-majors and non-minors may take Molecular Engineering courses on a P/F basis; only grades of C- or higher constitute passing work.

**Honors**

Students who pursue a substantive research project with a faculty member of the Pritzker School of Molecular Engineering are encouraged to write and defend an honors thesis based on their work. Often students initiate this research program during their third year and continue through their fourth year. Students who wish to be considered for honors are expected to complete their arrangements with the adviser for Molecular Engineering (Dr. Mark Stoykovich, stoykovich@uchicago.edu) before the end of their third year and to register for one quarter of MENG 29700 Undergraduate Research for Molecular Engineering during their third or fourth years.

To be eligible to receive honors, students in the BS degree program must write an honors paper describing their research and defend their thesis with an oral presentation. The honors paper and oral defense must be approved by faculty of the Pritzker School of Molecular Engineering and have deadlines established by the PME. The research paper or project used to meet this requirement may not be used to meet the BA/BS paper or project requirements in another major.

In addition, students must also have an overall GPA of 3.0 or higher to earn a BS degree with honors in Molecular Engineering.
Molecular Engineering Courses

MENG 20000. Introduction to Emerging Technologies. 100 Units.
This course will examine five emerging technologies (stem cells in regenerative medicine, quantum computing, water purification, new batteries, etc.) over two weeks each. The first of the two weeks will present the basic science underlying the emerging technology; the second of the two weeks will discuss the hurdles that must be addressed successfully to convert a good scientific concept into a commercial product that addresses needs in the market place.
Instructor(s): Matthew Tirrell, Mustafa Guler Terms Offered: Autumn
Prerequisite(s): Completion of the general education requirements in mathematics and physical or biological sciences
Equivalent Course(s): MENG 30000

MENG 20200. Introduction to Materials Science and Engineering. 100 Units.
Synthesis, processing and characterization of new materials are the pervasive, fundamental necessities for molecular engineering. Understanding how to design and control the structure and properties of materials at the nanoscale is the essence of our research and education program. This course will provide an introduction to molecularly engineered materials and material systems. The course starts with atomic-level descriptions and meanings of thinking about the structure of materials, and then builds towards understanding nano- and meso-scale materials architectures and their structure-dependent thermal, electrical, mechanical, and optical properties. Strategies in materials processing (heat treatment, diffusion, self-assembly) to achieve desired structure will also be introduced. In the latter part of the course, applications of the major concepts of the course will be studied in quantum materials, electronic materials, energy-related materials, and biomaterials.
Instructor(s): Shuolong Yang Terms Offered: Winter
Prerequisite(s): Completion of the general education requirements in mathematics and physical or biological sciences

MENG 20300. The Science, History, Policy, and Future of Water. 100 Units.
Water is shockingly bizarre in its properties and of unsurpassed importance throughout human history, yet so mundane as to often be invisible in our daily lives. In this course, we will traverse diverse perspectives on water. The journey begins with an exploration of the mysteries of water's properties on the molecular level, zooming out through its central role at biological and geological scales. Next, we travel through the history of human civilization, highlighting the fundamental part water has played throughout, including the complexities of water policy, privatization, and pricing in today's world. Attention then turns to technology and innovation, emphasizing the daunting challenges dictated by increasing water stress and a changing climate as well as the enticing opportunities to achieve a secure global water future.
Instructor(s): Seth Darling Terms Offered: Winter
Prerequisite(s): None
Equivalent Course(s): ENST 20300, HIPS 20301, HIST 25426, GLST 26807, ANTH 22131

MENG 21100. Molecular Science and Engineering of Water. 100 Units.
This course will cover the properties of the water molecule, hydrogen bonding, clusters, supercritical water, condensed phases, solutions, confined and interfacial water, clathrates, and nucleation. In addition, methods of water purification, water splitting and fuel cells, water in atmospheric and climate science, and water in biology, health and medicine will be discussed.
Instructor(s): James Skinner, Chong Liu Terms Offered: Autumn
Prerequisite(s): MENG 26201 or CHEM 26200 or PHYS 27900 (or concurrent)
Equivalent Course(s): MENG 31100

MENG 21600. Bioengineering Kinetics. 100 Units.
This course focuses on the kinetics of biochemical reactions at the molecular level and addresses basic questions at the interface between molecular engineering and cell biology. This course will equip students with the knowledge and tools to quantitatively solve problems in biochemical systems and molecular reactions that are dynamic or at equilibrium.
Instructor(s): Jun Huang Terms Offered: Spring
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): BIOS 21359

MENG 21900. Biological Physics. 100 Units.
This course is an introduction to the physics of living matter. Its goal is to understand the design principles from physics that characterize the condensed and organized matter of living systems. Topics include: basic structures of proteins, nucleotides, and biological membranes; application of statistical mechanics to diffusion and transport; hydrodynamics of low Reynolds number fluids; thermodynamics and chemical equilibrium; physical chemistry of binding affinity and kinetics; solution electrostatics and depletion effect; biopolymer mechanics; cellular mechanics and motions; molecular motors. Terms Offered: Spring
Prerequisite(s): PHYS 13300 or PHYS 14300
Note(s): Students majoring in Physics may use this course either as a Physics elective OR as a upper level elective in the Biological Sciences major.
Equivalent Course(s): BIOS 21506, PHYS 25500
MENG 22100. Chemical Kinetics and Reaction Engineering. 100 Units.
This course introduces the fundamental concepts of reaction kinetics, from the molecular mechanisms and reaction rates of chemical reactions to its applied aspects in the reaction engineering of complex chemical systems. Course topics will include elementary reactions and rate laws, collision theory, transition state theory, reaction dynamics, complex reacting systems, the steady-state hypothesis, heterogeneous catalysis, and diffusion-limited systems. The course will draw upon examples of industrial-scale chemical processes to consider the impact of kinetics on the engineering of batch and continuous-flow reactors.
Instructor(s): Xiaoying Liu Terms Offered: Spring
Prerequisite(s): MENG 26102 and MENG 26201

MENG 22500. Introduction to Polymer Science. 100 Units.
This course introduces the basics of polymer materials and their behavior and properties. The course will cover a general overview to polymers, basic terminology and definitions, their classification, and their applications. The mechanistic and kinetic behavior of the major classes of polymerization reactions (step-growth, chain addition, and "living" polymerizations) will be introduced with respect to control over polymer structure/architecture, size, and properties. The course will also discuss polymer properties, polymer thermodynamics, and basic structure-property relationships that provide polymers with their unique characteristics compared to small molecules. Techniques for characterizing the chemical and physical properties of polymer solutions will be introduced, including osmometry, viscometry, and gel permeation chromatography.
Instructor(s): Paul Nealey, Stuart Rowan Terms Offered: Autumn
Prerequisite(s): MENG 26201 or CHEM 26200
Equivalent Course(s): MENG 32510

MENG 23310. Experimental Techniques and Advanced Instrumentation. 100 Units.
This course aims to provide students with a knowledge of state-of-the-art experimental measurement techniques and laboratory instrumentation for applications in broad scientific research environments, as well as industrial and general engineering practice. Topics include atomic-scale structural and imaging methods, electronic transport in low dimensional matter, magnetic and optical characterization of materials. Basic concepts in electronic measurement such as lock-in amplifiers, spectrum and network analysis, noise reduction techniques, cryogenics, thermometry, vacuum technology, as well as statistical analysis and fitting of data will also be discussed.
Instructor(s): David Awschalom Terms Offered: Spring
Prerequisite(s): PHYS 23400 and PHYS 23500 for undergraduates
Equivalent Course(s): MENG 33310

MENG 23500. Foundations of Quantum Optics. 100 Units.
Quantum optics seeks to illuminate the fundamental quantum mechanics of the interaction of light and matter. These principles can form the basis for quantum technologies in areas such as cryptography, computation, and metrology. This course provides a foundation in the fundamental principles and applications of quantum optics. Topics to be discussed may include Fermi's Golden Rule, interaction of two-level atoms and light, spontaneous emission, Rabi oscillations, classical and non-classical photon statistics, beam splitters, atom cavity interaction, vacuum-Rabi splitting, coherence, entanglement, and teleportation. The course will assume that students are comfortable with single-particle quantum mechanics at the level of a typical introductory graduate-level course.
Instructor(s): Alex High Terms Offered: Winter
Prerequisite(s): PHYS 23400 and PHYS 23500, or CHEM 26100, or equivalent
Equivalent Course(s): MENG 33500

MENG 23700. Quantum Computation. 100 Units.
This course provides an introduction to the fundamentals of quantum information to students who have not had training in quantum computing or quantum information theory. Some knowledge of quantum mechanics is expected, including bra-ket notation and the time-dependent form of Schrodinger's equation. Students will learn how to carry out calculations and gain a fundamental grasp of topics that will include some or all of: entanglement, teleportation, quantum algorithms, cryptography, and error correction.
Instructor(s): Andrew Cleland Terms Offered: Winter
Prerequisite(s): PHYS 22100 or equivalent
Equivalent Course(s): MENG 33700

MENG 23710. Synthetic Biology. 100 Units.
The objective of this course is to provide an overview of the fundamentals of synthetic biology by exploration of published and primary literature. Synthetic biology is an interdisciplinary area that involves the application of engineering principles to biology. It aims at the (re-)design and fabrication of biological components and systems that do not already exist in the natural world. Our goal in the course will be to examine how to apply design principles to biological systems. This will require understanding how biological systems operate, what design principles are successful in biology, and a survey of current approaches in the field to tackle these challenges. Topics will include genetic manipulation, pathway engineering, protein design, cellular engineering, and tools for information input and output in biological systems.
Instructor(s): Aaron Esser-Kahn Terms Offered: Spring
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence. MENG 26102, BIOS 20236, and BIOS 20200 are recommended but not required.
Equivalent Course(s): MENG 33710
MENG 23800. Introduction to Nanofabrication. 100 Units.  
This course will cover the fundamentals of nanofabrication from a practical viewpoint and will be useful for students planning to pursue research involving semiconductor processing technology, as well as broader topics such as microelectromechanical systems (MEMS), quantum devices, optoelectronics, and microfluidics. This course will cover the theory and practice of lithographic patterning; physical and chemical vapor deposition; reactive plasma etching; wet chemical processing; characterization techniques; and other special topics related to state-of-the-art processes used in the research and development of nanoscale devices. A solid grounding in introductory chemistry and physics is expected.  
Instructor(s): Peter Duda Terms Offered: Winter  
Prerequisite(s): PHYS 13300 and CHEM 10200, or equivalent  
Equivalent Course(s): MENG 33800

MENG 24100-24200. Selected Topics in Molecular Engineering: Molecular/Materials Modeling I-II.  
Molecular modeling seeks to develop models and computational techniques for classical mechanical prediction of the structure, thermodynamic properties, and non-equilibrium behavior of gases, liquids, and solids from their intermolecular interactions.  

MENG 24100. Selected Topics in Molecular Engineering: Molecular/Materials Modeling I. 100 Units. 
This course will introduce students to the methods of molecular modeling. The topics covered will include an introduction to the origin of molecular forces, a brief introduction to statistical mechanics and ensemble methods, and an introduction to molecular dynamics, Brownian dynamics, and Monte Carlo simulations. The course will also cover elements of advanced sampling techniques, including parallel tempering, umbrella sampling, and other common biased sampling approaches. Course work or research experience is strongly recommended in: (1) elementary programming (e.g., C or C++), and (2) physical chemistry or thermodynamics.  
Instructor(s): Andrew Ferguson Terms Offered: Winter  
Prerequisite(s): MATH 20100 or PHYS 22100, and MENG 26201 or PHYS 27900 or CHEM 26200  
Equivalent Course(s): MENG 34100

MENG 24200. Selected Topics in Molecular Engineering: Molecular/Materials Modeling II. 100 Units. 
Quantum mechanical methods, including quantum chemistry, density functional theory (DFT), and many body perturbation theory, for simulating the properties of molecules and materials will be explored in this course. Numerical algorithms and techniques will be introduced that allow for solution of approximate forms of the Schroedinger and Boltzmann Equations that model structural and transport properties of molecules and materials. The coupling of DFT with molecular dynamics will be detailed for determining finite temperature properties. Coupling of DFT with spin Hamiltonians to study dynamical spin correlations in materials will also be described. Examples of the application of quantum mechanical methods to materials for energy conversion and quantum information technologies will be provided.  
Instructor(s): Giulia Galli Terms Offered: Spring  
Prerequisite(s): PHYS 23400 or CHEM 26100 or instructor consent  
Equivalent Course(s): MENG 34200

MENG 24300. The Engineering and Biology of Tissue Repair. 100 Units. 
In this course, students will gain an understanding of the science and application of tissue engineering, a field that seeks to develop technologies for restoring lost function in diseased or damaged tissues and organs. The course will first introduce the underlying cellular and molecular components and processes relevant to tissue engineering: extracellular matrices, cell/matrix interactions such as adhesion and migration, growth factor biology, stem cell biology, inflammation, and innate immunity. The course will then discuss current approaches for engineering a variety of tissues, including bone and musculoskeletal tissues, vascular tissues, skin, nerve, and pancreas. Students will be assessed through in-class discussions, take-home assignments and exams, and an end-of-term project on a topic of the student's choice.  
Instructor(s): Jeffrey Hubbell Terms Offered: Spring  
Prerequisite(s): BIOS 20180 or BIOS 20234  
Equivalent Course(s): MPMM 34300, MENG 34300, BIOS 21507
MENG 24310. Cellular Engineering, 100 Units.
Cellular engineering is a field that studies cell and molecule structure-function relationships. It is the development and application of engineering approaches and technologies to biological molecules and cells. This course provides a bridge between engineers and biologists that quantitatively study cells and molecules and develop future clinical applications. Topics include fundamental cell and molecular biology; immunology and biochemistry; receptors, ligands, and their interactions; nanotechnology/biomechanics; enzyme kinetics; molecular probes; cellular and molecular imaging; single-cell genomics and proteomics; genetic and protein engineering; and drug delivery and gene delivery.
Instructor(s): Jun Huang Terms Offered: Winter
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): MENG 343110, BIOS 21508, MOMN 34310

MENG 24400. Nanomedicine, 100 Units.
This course focuses on the applications of nanotechnology in medicine. The chemical, physical and biological features of the nanomaterials will be discussed for applications in medicine. A survey of concepts in therapeutic drug delivery methods, diagnostic imaging agents and cell-materials interactions will be discussed.
Instructor(s): Mustafa Guler Terms Offered: Winter
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): BIOS 28410, MENG 34400

MENG 24500. Microfluidics and Its Applications, 100 Units.
Precision control of fluids at the micrometer scale (hence microfluidics) provides unprecedented capabilities in manipulation and analysis of cells and proteins. Moreover, fluids and particles behave in fundamentally different ways when confined to small dimensions, making microfluidics an interesting topic of basic research. This course aims to provide students with theoretical knowledge and practical skills on the use of microfluidics for the manipulation and analysis of physical, chemical, and biological systems. We will first survey theoretical concepts regarding microfluidics. We will then focus on design considerations and fabrication methods for multi-layer microfluidic chips using PDMS soft-lithography. We will learn how to fabricate, multiplex, and control PDMS membrane valves and integrate them into high-throughput analytical systems. We will survey recent developments in microfluidics and its scientific and industrial applications. Biological systems analysis in cell sorting, culture, cell signaling, single molecule detection, digital nucleic acid and protein quantification, and biosensing are some of the applications we will cover. This course will have a laboratory component where students will design, fabricate, and use microfluidic devices and therefore acquire hands-on skills in microfluidic engineering.
Instructor(s): Savas Tay Terms Offered: Spring
Prerequisite(s): MATH 13300 (or higher), or MATH 13200 (or higher) plus BIOS 20151 or BIOS 20152 or BIOS 20236
Equivalent Course(s): MENG 34500

MENG 24600. Quantitative Systems Biology, 100 Units.
This course aims to provide students with knowledge on the use of modern methods for the analysis, manipulation, and modeling of complex biological systems, and to introduce them to some of the most important applications in quantitative and systems biology. We will first survey theoretical concepts and tools for analysis and modeling of biological systems like biomolecules, gene networks, single cells, and multicellular systems. Concepts from information theory, biochemical networks, control theory, and linear systems will be introduced. Mathematical modeling of biological interactions will be discussed. We will then survey quantitative experimental methods currently used in systems biology. These methods include single cell genomic, transcriptomic, and proteomic analysis techniques, in vivo and in vitro quantitative analysis of cellular and molecular interactions, single molecule methods, live cell imaging, high throughput microfluidic analysis, and gene editing. Finally, we will focus on case studies where the quantitative systems approach made a significant difference in the understanding of fundamental phenomena like signaling, immunity, development, and diseases like infection, autoimmunity, and cancer.
Instructor(s): Savas Tay Terms Offered: Winter
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): MENG 34600

MENG 24700. Biodiagnostics and Biosensors, 100 Units.
This course focuses on the biological and chemical interactions that are important for the diagnosis of diseases and the design of new assays. The principles and mechanisms of molecular diagnostics and biosensors, as well as their applications in disease diagnosis, will be discussed. Bioanalytical methods including electrochemical, optical, chemical separation, and spectroscopic will be described. Surface functionalization and biomolecular interactions will be presented for the development of protein and DNA based biosensor applications. The goals for the course are to introduce the fundamental mechanisms of bioanalytical methods/tools, examples of specific methods for diagnostic purposes, and analytical methods necessary for developing new precision medicine tools.
Instructor(s): Mustafa Guler Terms Offered: Spring
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): MENG 34700, BIOS 28700
MENG 24800. Quantitative Immunobiology. 100 Units.
The science of immunology was born at the end of the 19th century as a discipline focused on the body's defenses against infection. The following 120+ years has led to the discovery of a myriad of cellular and molecular players in immunity, placing the immune system alongside the most complex systems such as Earth’s global climate and the human brain. The functions and malfunctions of the immune system have been implicated in virtually all human diseases. It is thought that cracking the complexity of the immune system will help manipulate and engineer it against some of the most vexing diseases of our times such as AIDS and cancer. To tackle this complexity, immunology in the 21st century - similar to much of the biological sciences - is growing closer to mathematics and data sciences, physics, chemistry and engineering. A central challenge is to use the wealth of large datasets generated by modern day measurement tools in biology to create knowledge, and ultimately predictive models of how the immune system works and can be manipulated. The goal of this course is to introduce motivated students to the quantitative approaches and reasoning applied to fundamental questions in immunology. Instructor(s): Nicolas Chevrier Terms Offered: Winter
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence. Knowledge of R is recommended but not required. Courses in immunology and microbiology are an advantage but not required (e.g., BIOS 25256 Immunobiology; BIOS 25206 Fundamentals of Bacterial Physiology).
Equivalent Course(s): IMMU 34800, MENG 34800, BIOS 26403

MENG 25000. Introduction to the Design Process. 100 Units.
Design is as much a way of thinking as it is a process for creating anything new. This course introduces design methods for the early-stage of an innovation process. It will cover problem framing, contextual and user research, mining qualitative information for insights and unmet needs, concept generation, prototyping, and communications for innovation. Classes will be a combination of lectures, hands-on learning, and a quarter-long design project focused on a real-world challenge. Instructor(s): Angelika Zissimopoulos Terms Offered: Spring
Prerequisite(s): MENG 20000 and completion of the general education requirements in mathematics and physical or biological sciences.

MENG 25100. Electrochemical Principles and Methods. 100 Units.
This course will cover topics related to basic electrochemical principles, methodologies, and systems. In particular, students will be given an overview of fundamental concepts related to electrochemical potential, electric double layer, electrode kinetics, and mass transport processes. In addition, the application of key electrochemical experimental methods will be covered. A few examples include cyclic voltammetry, AC impedance spectroscopy, and the rotating disk electrode. Throughout the course, students will apply basics principles of thermodynamics, kinetics, and transport phenomena. Lastly, a brief overview of traditional electrochemical systems and emerging technologies related to energy storage and conversion (e.g., lithium-ion batteries, flow batteries, and fuel cells) and bioelectronics applications will be discussed. Instructor(s): Shrayesh Patel Terms Offered: Spring
Prerequisite(s): MENG 26102 and MENG 26201
Equivalent Course(s): MENG 35100

MENG 26010. Engineering Principles of Conservation. 100 Units.
This course is a precursor to both the thermodynamics and transport sequences. Students will be introduced to the mathematical framework of Reynolds transport theorem from a general perspective and in different forms (algebraic, integral and differential), and apply that framework to a wide variety of problems that involve changes in mass, energy, and momentum. Using scaling approximations and dimensional analysis to obtain an intuitive understanding of the mathematical framework will also be emphasized throughout. These concepts will then be carried over to, and reinforced in, the transport and thermodynamics courses that follow sequentially. Instructor(s): Mark Stoykovich, Andrew Ferguson Terms Offered: Spring
Prerequisite(s): MATH 20000 or MATH 20400 or PHYS 22000, and CHEM 11300 or PHYS 13300

MENG 26020. Engineering Electrodynamics. 100 Units.
This is an advanced course in electromagnetism with an engineering focus. Requires good preparation in freshman-level, calculus-based, electrostatics and magnetostatics; also preparation in vector calculus. Instructor(s): Andrew Cleland Terms Offered: Spring
Prerequisite(s): PHYS 13300 or PHYS 14300, and MATH 20100 or PHYS 22100 or concurrent enrollment in MATH 20500 or MATH 20900

MENG 26030. Introduction to Engineering Analysis. 100 Units.
This course provides students with the enabling numerical algorithms and computational methods for molecular engineering. These numerical methods include root finding, solving systems of linear and non-linear equations, general minimization and optimization strategies, regression analysis, and Monte Carlo techniques. Numerical integration including Runge-Kutta methods, as well as methods for solving ODEs (i.e., initial value problems and boundary value problems) and PDEs, will also be introduced. A key focus of the course will be to introduce the students to basic structured programming in Python or MATLAB that will provide a foundational tool for applying such algorithms throughout the MENG coursework. Instructor(s): Mark Stoykovich Terms Offered: Autumn
Prerequisite(s): MENG 26010 or MENG 26020

MENG 26101-26102. Transport Phenomena I: Forces + Flows; Transport Phenomena II.
The Transport sequence exposes students to basic topics in continuum mechanics, with a focus on momentum transfer (part I) and energy and mass transfer (part II).
MENG 26101. Transport Phenomena I: Forces and Flows. 100 Units.
This course will expose students to basic topics in continuum mechanics, with a focus on momentum transfer. Course topics include an overview of tensor mathematics, forces and inertia, Bernoulli’s Equation, Navier-Stokes Equations, and standard examples of Navier-Stokes flows, including Poiseuille flow, falling films, and flow around a sphere. For each of these topics, examples will be provided with dimensionless and scaling analysis to accompany problem solution. Analysis will include computation of approximate solutions, determination of when an approximate solution is adequate and, given the assumptions made, what the limitations of any solution are. Laboratory exercises in microfluidics will be included. (L)
Prerequisite(s): MENG 26010
Instructor(s): Shrayesh Patel Terms Offered: Autumn

MENG 26102. Transport Phenomena II. 100 Units.
This course exposes students to basic topics in continuum mechanics, with a focus on energy and mass transfer. Course topics include an overview of the physical and mathematical basis of diffusion, Fick’s law and the definition of fluxes for description in the form of differential equations, a reminder of the Reynolds Transport Theorem and differential forms for mass and energy transfer, mass balances in non-reacting systems (with multiple examples), mass balances with chemical reactions, energy balances, and combined energy and mass balances with chemical reactions.
Instructor(s): Melody Swartz, Aaron Esser-Kahn Terms Offered: Winter
Prerequisite(s): MENG 26101

MENG 26102. Transport Phenomena II. 100 Units.
This course exposes students to basic topics in continuum mechanics, with a focus on energy and mass transfer. Course topics include an overview of the physical and mathematical basis of diffusion, Fick’s law and the definition of fluxes for description in the form of differential equations, a reminder of the Reynolds Transport Theorem and differential forms for mass and energy transfer, mass balances in non-reacting systems (with multiple examples), mass balances with chemical reactions, energy balances, and combined energy and mass balances with chemical reactions.
Instructor(s): Melody Swartz, Aaron Esser-Kahn Terms Offered: Winter
Prerequisite(s): MENG 26101

MENG 26201-26202. Thermodynamics and Statistical Mechanics I-II.
This sequence covers thermodynamics and statistical mechanics for engineers.

MENG 26201. Thermodynamics and Statistical Mechanics I. 100 Units.
This course will include an introduction to postulates of thermodynamics, thermodynamic properties of pure substances, and engineering applications relying on thermodynamic cycles (including engines, heat pumps, and refrigeration). An introduction to statistical mechanics and its connection to molecular thermodynamics will also be included among the course topics. (L)
Instructor(s): Chong Liu Terms Offered: Winter
Prerequisite(s): MENG 26030

MENG 26202. Thermodynamics and Statistical Mechanics II. 100 Units.
This course addresses the thermodynamics of mixtures and their phase equilibria (e.g., vapor-liquid, liquid-liquid, and solid-liquid equilibria). It includes an introduction to the theory of phase equilibria and stability for mixtures, the concepts of activity and fugacity for describing non-ideal systems, an introduction to molecular models and the prediction of thermodynamic properties from such models, as well as the importance of such topics for engineering applications (including in separation processes such as distillation, extraction, and membrane osmosis). The course has a laboratory component that includes characterizing vapor-liquid equilibria in distillation processes, experimentation with surface adsorption, and measurements of solubility. (Lab)
Instructor(s): Mark Stoykovich Terms Offered: Spring
Prerequisite(s): MENG 26201

MENG 26202. Thermodynamics and Statistical Mechanics II. 100 Units.
This course addresses the thermodynamics of mixtures and their phase equilibria (e.g., vapor-liquid, liquid-liquid, and solid-liquid equilibria). It includes an introduction to the theory of phase equilibria and stability for mixtures, the concepts of activity and fugacity for describing non-ideal systems, an introduction to molecular models and the prediction of thermodynamic properties from such models, as well as the importance of such topics for engineering applications (including in separation processes such as distillation, extraction, and membrane osmosis). The course has a laboratory component that includes characterizing vapor-liquid equilibria in distillation processes, experimentation with surface adsorption, and measurements of solubility. (Lab)
Instructor(s): Mark Stoykovich Terms Offered: Spring
Prerequisite(s): MENG 26201
MENG 27100. Biological Materials. 100 Units.
In this course, students will gain an understanding of the science and application of biomaterials, a field that utilizes fundamental principles of materials science with cell biology for applications in therapeutics and diagnostics. The course will introduce the basic classes of biomaterials, considering metals used in medicine, ceramics and biological inorganic materials such as hydroxyapatite, and polymers used in medicine. The basis of protein adsorption modulating biological interactions with these materials will be elaborated. Examples to be covered in the course will include polymers used in drug delivery, polymers used in protein therapeutics, polymers used in degradable biomaterial implants, polymers used in biodiagnostics, and hybrid and polymeric nanomaterials used as bioactives and bioactive carriers. An emphasis in the course will be placed on bioactive materials development. Students will be assessed through in-class discussions, take-home assignments and exams, and an end-of-term project on a topic of the student's choice.
Instructor(s): Jeffrey Hubbell and Mustafa Guler Terms Offered: Autumn
Prerequisite(s): BIOS 20186 and BIOS 20187, or BIOS 20234 and BIOS 20235
Note(s): This course does not meet the requirements for the Biological Sciences major.
Equivalent Course(s): BIOS 29328, MENG 37100

MENG 27200. Electronic and Quantum Materials for Technology. 100 Units.
This is a one-quarter introductory course on the science and engineering of electronic and quantum materials. The intended audience is upper-level undergraduate students and first-year graduate students in Molecular Engineering and other related fields, including Chemistry and Physics. We will learn the basics of electrical and optical properties of electronic materials, including semiconductors, metals, and insulators starting from a simple band picture, and will discuss how these materials enable modern electronic and optoelectronic devices and circuitry. We will also explore the modern synthesis techniques for these materials and the effects of reduced dimensions and emergent quantum properties. No comprehensive exposure to quantum mechanics, thermodynamics, or advanced mathematical skills will be assumed, even though working knowledge of these topics will be helpful.
Instructor(s): Jiwoong Park Terms Offered: Spring
Prerequisite(s): CHEM 26200 or PHYS 23500 or instructor consent
Equivalent Course(s): MENG 37200

MENG 27300. Polymer Physics. 100 Units.
This course is an advanced introduction to polymer physics taught at a level suitable for senior undergraduates and graduate students in STEM fields. Topics that will be covered include the statistics and conformations of linear chain molecules; polymer brushes; thermodynamics and dynamics of polymers, polymer blends and polymer solutions; phase equilibria; networks, gels, and rubber elasticity; linear viscoelasticity; and thermal and mechanical properties.
Instructor(s): Paul Nealey Terms Offered: Winter
Prerequisite(s): MENG 22500
Equivalent Course(s): MENG 32500

MENG 27320. Polymer Synthesis. 100 Units.
This course introduces the most important polymerization reactions, focusing on their reaction mechanisms and kinetic aspects. Topics include free radical and ionic chain polymerization, step-growth polymerization, ring-opening, insertion, controlled living polymerization, crosslinking, copolymerization, and chemical modification of preformed polymers.
Instructor(s): Stuart Rowan Terms Offered: Winter
Prerequisite(s): CHEM 22000 and CHEM 22100
Equivalent Course(s): MENG 32520

MENG 29511-29512. Engineering Design I-II.
The project-based design courses combine fundamental science and engineering skills to solve open-ended and challenging engineering problems selected among those encountered in the biology, chemical and soft materials, and quantum fields. Specific objectives for the courses include learning how to define a technical problem and how to propose solutions, applying scientific and engineering knowledge to solve real-world problems, and developing an operating plan with defined sub-tasks and project timelines. Additional emphasis will be placed on enhancing skills to communicate results clearly and concisely to various audiences, access and manage resources to achieve objectives, work as part of a team, and interact with external mentors and project managers. These courses also serve as a vehicle to teach other equally important non-technical skills, such as professional and ethical responsibilities in engineering and the impact of engineering in a societal context.

MENG 29511. Engineering Design I. 100 Units.
First quarter of Engineering Design.
Instructor(s): Mark Stoykovich, Xiaoying Liu, Mustafa Guler Terms Offered: Autumn
Prerequisite(s): Instructor consent required

MENG 29512. Engineering Design II. 100 Units.
Second quarter of Engineering Design.
Instructor(s): Mark Stoykovich, Xiaoying Liu, Mustafa Guler Terms Offered: Winter
Prerequisite(s): MENG 29511

MENG 29512. Engineering Design II. 100 Units.
Second quarter of Engineering Design.
Instructor(s): Mark Stoykovich, Xiaoying Liu, Mustafa Guler Terms Offered: Winter
Prerequisite(s): MENG 29511
MENG 29700. Undergraduate Research for Molecular Engineering. 100 Units.
IME faculty offer one-quarter research experiences for interested MENG students. A quality grade will be given based on performance in this course. In order to assign a quality grade, an agreement between the sponsoring IME faculty member and each student will be made that includes: (1) the content and scope of the project, (2) expectations for time commitment, (3) a well-defined work plan with timelines for particular experiments or calculations to be accomplished, and (4) a summary of academic goals such as demonstrating knowledge of the literature and developing communication skills (e.g., through presentations at group meetings).
Instructor(s): PME Faculty Terms Offered: Autumn Spring Winter
Prerequisite(s): Faculty consent required
Note(s): Students interested in MENG 29700 should contact the adviser for Molecular Engineering (Dr. Mark Stoykovich, stoykovich@uchicago.edu) and complete a “College Reading and Research Course Form” available from the College advisers.
Font Notice

This document should contain certain fonts with restrictive licenses. For this draft, substitutions were made using less legally restrictive fonts. Specifically:

    Times was used instead of Trajan.
    Times was used instead of Palatino.

The editor may contact Leepfrog for a draft with the correct fonts in place.