Molecular Engineering

Department Website: https://pme.uchicago.edu/academics/undergraduate-program-molecular-engineering (https://pme.uchicago.edu/academics/undergraduate-program-molecular-engineering/)

Overview of Molecular Engineering

Engineering focuses on solving complex technological problems and, in the case of molecular engineering, applying molecular-level science to the design of advanced devices and systems, processes, and technologies. The Pritzker School of Molecular Engineering (PME) is at the forefront of developing advanced molecular technologies to address pressing global and societal challenges, like those found in the fields of quantum computing and materials, cancer treatment, water use and purification, energy storage, and regenerative medicine.

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. 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 prepares undergraduates for leadership roles in a technology-driven society. Graduates will be positioned to follow traditional engineering paths in research, technology development, and manufacturing, or to pursue further postgraduate study in such fields as engineering, science, medicine, business, or law. Other graduates may successfully leverage the quantitative and problem-solving skills gained in their training as engineers towards careers in technical and management consulting, finance, public policy, or entrepreneurship.

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, <u>and</u> physics course work concurrently during the first year at the University of Chicago is highly recommended for students who receive mathematics placements in MATH 15200 or higher. 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. Doing so will enable interested students to pursue specialization minors in Molecular Engineering (for example, in quantum information science, immunoengineering, polymers and soft materials, or sustainable energy and water resources), advanced electives, research projects, and other opportunities beyond the required major course work. Completion of at least MATH 18400, CHEM 11300, and PHYS 13300, or approved equivalents, before the beginning of second year **<u>is a prerequisite for Molecular Engineering course work</u>** during a student's second year.

Students who receive mathematics placement into MATH 15100 have the choice of whether to take mathematics, chemistry, and physics course work during first year. If such a student decides to concurrently pursue mathematics, chemistry, and physics course work in the first year, then it is strongly advised that they also plan to take MATH 18400 during the summer between the first and second years, which will allow them to start their Molecular Engineering course work in the second year. Completion of at least MATH 18400, CHEM 11300, and PHYS 13300, or approved equivalents, before the beginning of the second year **<u>is a prerequisite for Molecular Engineering course work</u>** during a student's second year. Alternatively, students can decide to take mathematics and chemistry if on the Bioengineering or Chemical Engineering tracks, or mathematics and physics if on the Quantum Engineering track, during the first year alongside their general education courses. Students following this path 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 may be unable to avail themselves of some advanced engineering opportunities.

Students who receive mathematics placement into MATH 13100 have opportunities to complete the Molecular Engineering major in four years. Such students should take the MATH 130s and general chemistry sequences in the first year, followed by the MATH 180s and general physics sequences in the second year. Students following this path 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.

Sample four-year plans for the Molecular Engineering program are provided below that highlight these different starting points and pathways through the major requirements.

2. Starting the program. All students begin their Molecular Engineering coursework by enrolling in MENG 21100 Principles of Engineering Analysis I once they have completed MATH 18400 and satisfied the chemistry and physics prerequisites. This course is offered in the Autumn Quarter only. Students are encouraged to take this course during their second year of studies, which enables them to more easily access the specialization minors in Molecular Engineering, advanced electives, research and design projects, and other opportunities beyond the required major course work.

3. Foundations in Molecular Engineering. All Molecular Engineering majors take a set of five courses as a cohort that develop a shared skill set essential for engineering at the atomistic, molecular, and nano scales. These courses include MENG 21100-21200 Principles of Engineering Analysis I and II which provide engineering problem-solving and system analysis skills, numerical methods, and computational tools critical to analyzing quantitative problems across all engineering fields, as well as MENG 21300 Engineering Quantum Mechanics, MENG 21400 Molecular Engineering Thermodynamics, and MENG 21500 Molecular Engineering Transport Phenomena.

4. Three Molecular Engineering tracks. Another strength of the Molecular Engineering program is that students select one of three tracks—bioengineering, chemical engineering, or quantum engineering—to concentrate and deepen knowledge in the area that interests them the most. Designed to reflect the research and education themes of the Pritzker School of Molecular Engineering, each track consists of five or six courses, as follows:

- **Bioengineering Track** includes a bioengineering laboratory and courses in organic chemistry, biochemistry, quantitative physiology, systems biology, and cellular engineering.
- **Chemical Engineering Track** includes courses in organic chemistry, fluid mechanics, kinetics and reaction engineering, and the thermodynamics of mixtures.
- **Quantum Engineering Track** includes courses in quantum mechanics and engineering, electricity and magnetism, optics, electrodynamics, quantum computation, and laboratory instrumentation.

5. MENG 21800-21900 Engineering Design I-II (200-unit capstone design sequence). The design course is a two-quarter sequence that teaches students how to combine fundamental science and engineering to address open-ended, real-world challenges. Engineers from industry and the national laboratories propose real-world projects for which they serve as mentors. Students work together in small teams throughout the two quarters to address the diverse engineering challenges that arise. Examples of recent design projects that have been undertaken by Molecular Engineering majors include developing self-cleaning textiles that photocatalytically degrade microbial contaminants; applying machine learning to analyze ultrafast X-ray images of liquid jets and sprays; and evaluating the technical and economic barriers of emerging approaches to plastic recycling.

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

Alternatively, students may elect to pursue MENG 21810 Engineering Research: Strategies and Tactics I-MENG 21910 Engineering Research: Strategies and Tactics II **(200-unit capstone research sequence)** should they be particularly focused on the academic research endeavor. All Molecular Engineering students are strongly encouraged to build hands-on research experiences by pursuing projects with faculty in the PME, across the University of Chicago, or at Argonne National Laboratory. This capstone research sequence enables students to formalize this experience and add valuable skills to their research repertoire. Research projects are independently identified and arranged by the students via communication with faculty. However, students who choose to complete the two-quarter research sequence are provided a structured introduction to the research process and are exposed to many of the aforementioned non-technical skills, including problem identification, project planning, experimental design, communication skills, IP topics, and teamwork, which they can put into practice in their laboratories and research experiences.

6. Laboratory skills and hands-on experience. Molecular engineers should develop the ability to apply their knowledge of mathematics, science, and engineering; to design and conduct experiments; and to analyze and interpret data. Molecular Engineering majors develop these skills through laboratory components associated with the required courses in the physical and biological sciences, as well as Molecular Engineering courses including MENG 24100 Molecular Engineering Thermodynamics of Phase Equilibria, MENG 24200 Molecular Transport Phenomena II: Fluid Flow and Convective Transport Processes, MENG 24400 Chemical Kinetics and Reaction Engineering, MENG 26200 QuantumLab, MENG 23000 Experimental Bioengineering Laboratory, and optionally MENG 23310 Immunoengineering Laboratory.

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

GENERAL EDUCATION

CHEM 10100 & CHEM 10200	Introductory General Chemistry I and Introductory General Chemistry II (or higher) [1]	200
One of the following sequences:		200
BIOS 20186-20187	Fundamentals of Cell and Molecular Biology; Fundamentals of Genetics [2]	
BIOS 20234 & BIOS 20235	Molecular Biology of the Cell and Biological Systems [3]	
Total Units		400

MAJOR

CHEM 11300	Comprehensive General Chemistry III (or higher) [1]	100
PHYS 13100-13200-13300	Mechanics; Electricity and Magnetism; Waves, Optics, and Heat (or higher)	300
MATH 18300-18400-18500	Mathematical Methods in the Physical Sciences I-II-III [4]	300
MENG 21100	Principles of Engineering Analysis I	100
MENG 21200	Principles of Engineering Analysis II	100
MENG 21300	Engineering Quantum Mechanics	100
MENG 21400	Molecular Engineering Thermodynamics	100
MENG 21500	Molecular Engineering Transport Phenomena	100
One of the following sequences:		200
MENG 21800-21900	Engineering Design	
MENG 21810-21910	Engineering Research: Strategies and Tactics	
CHEM 22000 & CHEM 22100	Organic Chemistry I and Organic Chemistry II	200
BIOS 20200	Introduction to Biochemistry	100
MENG 23000	Experimental Bioengineering Laboratory	100
One of the following:		100
MENG 22100	Quantitative Physiology	
MENG 22200	Cellular Engineering	
MENG 22300	Quantitative Systems Biology	
MENG 23200	Principles of Immunology	
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.

4 MATH 20300-20400-20500 Analysis in Rn I-II-III or MATH 20700-20800-20900 Honors Analysis in Rn I-II-III may be used to fulfill this requirement.

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

GENERAL EDUCATION

CHEM 10100 & CHEM 10200	Introductory General Chemistry I and Introductory General Chemistry II (or higher) [1]	200
One of the following sequences:		200
BIOS 20186-20187	Fundamentals of Cell and Molecular Biology; Fundamentals of Genetics [2]	
BIOS 20234 & BIOS 20235	Molecular Biology of the Cell and Biological Systems [3]	
Total Units		400

MAJOR

CHEM 11300	Comprehensive General Chemistry III (or higher) [1]	100
PHYS 13100-13200-13300	Mechanics; Electricity and Magnetism; Waves, Optics, and Heat (or higher)	300

MATH 18300-18400-18500	Mathematical Methods in the Physical Sciences I-II-III [4]	300
MENG 21100	Principles of Engineering Analysis I	100
MENG 21200	Principles of Engineering Analysis II	100
MENG 21300	Engineering Quantum Mechanics	100
MENG 21400	Molecular Engineering Thermodynamics	100
MENG 21500	Molecular Engineering Transport Phenomena	100
One of the following sequences:		200
MENG 21800-21900	Engineering Design	
MENG 21810-21910	Engineering Research: Strategies and Tactics	
CHEM 22000 & CHEM 22100	Organic Chemistry I and Organic Chemistry II	200
MENG 24100	Molecular Engineering Thermodynamics of Phase Equilibria	100
MENG 24200	Molecular Transport Phenomena II: Fluid Flow and Convective Transport Processes	100
MENG 24400	Chemical Kinetics and Reaction Engineering	100
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.
3. Open only to students with a 4 or 5 on the AP Biology exam.
4. MATH 20300-20400-20500 Analysis in Rn I-II-III or MATH 20700-20800-20900 Honors Analysis in Rn I-II-III may be used to fulfill this requirement.

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

GENERAL EDUCATION

PHYS 13100-13200	Mechanics; Electricity and Magnetism (or higher)	200
Total Units		200

MAJOR

PHYS 13300	Waves, Optics, and Heat (or higher)	100
CHEM 10100 & CHEM 10200 & CHEM 11300	Introductory General Chemistry I and Introductory General Chemistry II and Comprehensive General Chemistry III (or higher) [1]	300
MATH 18500 & MATH 18600	Mathematical Methods in the Physical Sciences III and Mathematics of Quantum Mechanics [2]	200
MENG 21100	Principles of Engineering Analysis I	100
MENG 21200	Principles of Engineering Analysis II	100
MENG 21300	Engineering Quantum Mechanics [3]	100
MENG 21400	Molecular Engineering Thermodynamics	100
MENG 21500	Molecular Engineering Transport Phenomena	100
One of the following sequences:		200
MENG 21800-21900	Engineering Design	
MENG 21810-21910	Engineering Research: Strategies and Tactics	
MENG 26100-26110	Intermediate Quantum Engineering I-II [3]	200
MENG 26200	QuantumLab	100
PHYS 22500-22700	Intermediate Electricity and Magnetism I-II	200
One of the following:		100
MENG 26300	Engineering Electrodynamics	
MENG 26400	Quantum Computation	
MENG 26500	Foundations of Quantum Optics	
MENG 26510	Optics and Photonics	
MENG 26600	Electronic and Quantum Materials for Technology	
MENG 26610	Science of Materials	

MENG 26620	Physics of Solid State Semiconductor Devices	
MENG 26630	Introduction to Nanofabrication	
Total Units		1900

1 Credit may be granted by examination.

2 MATH 20400 Analysis in Rn II-MATH 20500 Analysis in Rn III or MATH 20800 Honors Analysis in Rn II-MATH 20900 Honors Analysis in Rn III may be used to fulfill this requirement.

3 Students double majoring in Molecular Engineering and Physics should contact the Director of Undergraduate Studies for Molecular Engineering to discuss options related to the three course quantum mechanics sequence MENG 21300 Engineering Quantum Mechanics, MENG 26100 Intermediate Quantum Engineering, and MENG 26110 Intermediate Quantum Engineering II.

Sample Major Programs and Four-Year Plans

Sample four-year programs for the Molecular Engineering major are provided below. These are suggestions for possible student trajectories through the major, but do not represent the only four-year programs that would lead to completion of the Molecular Engineering major requirements. Study Abroad (http://collegecatalog.uchicago.edu/thecollege/offcampusstudyprograms/) can often be included alongside the Molecular Engineering major, with Winter or Spring Quarters of the third year, as well as September Term, often providing the ideal opportunity for many students, although situations vary depending on track and progress through the major. Students should rely on the direction of the Molecular Engineering and College advisers, as well as relevant placement tests, in creating a personalized four-year program that accommodates their individual backgrounds and interests.

Bioengineering Track - *Four-year plan based on mathematics placement in MATH 18300.* *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. Note that the organic chemistry courses (CHEM 22000-22100) could be moved to third-year without other adjustments to the plan outlined here.*

First Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 18300	MATH 18400	MATH 18500
CHEM 10100	CHEM 10200	CHEM 11300
PHYS 13100	PHYS 13200	PHYS 13300
HUMA	HUMA	ART
Second Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21100	MENG 21200	MENG 21400
CHEM 22000	MENG 21300	BIOS 20186
SOSC	CHEM 22100	SOSC
	SOSC	
Third Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21500	MENG elective	MENG 23000
BIOS 20187	CIV	BIOS 20200
CIV		CIV / ART
Fourth Year		
Autumn Quarter	**Winter Quarter**	
MENG 21800 or 21810	MENG 21900 or 21910	

Bioengineering Track - *Four-year plan based on mathematics placement in MATH 15100.* *This example program for the Molecular Engineering major does not require completion of mathematics, chemistry, and physics sequences during a student's first year at the University. A similar four-year plan can be developed for students placed into MATH 13100.*

First Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 15100	MATH 15200	MATH 18300
CHEM 10100	CHEM 10200	CHEM 11300
HUMA	HUMA	BIOS 20186
		ART
Second Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 18400	MATH 18500	PHYS 13300
PHYS 13100	PHYS 13200	SOSC
BIOS 20187	SOSC	
SOSC		

Third Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21100	MENG 21200	MENG 21400
CHEM 22000	MENG 21300	MENG 23000
CIV	CHEM 22100	CIV / ART
	CIV	

Fourth Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21500	MENG 21900 or 21910	BIOS 20200
MENG 21800 or 21810	MENG elective	

Chemical Engineering Track - *Four-year plan based on mathematics placement in MATH 18300.* *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. Note that the organic chemistry courses (CHEM 22000-22100) could be moved to the third year without other adjustments to the plan outlined here.*

First Year

Autumn Quarter	Winter Quarter	Spring Quarter
MATH 18300	MATH 18400	MATH 18500
CHEM 10100	CHEM 10200	CHEM 11300
PHYS 13100	PHYS 13200	PHYS 13300
HUMA	HUMA	ART

Second Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21100	MENG 21200	MENG 21400
CHEM 22000	MENG 21300	BIOS 20186
SOSC	CHEM 22100	SOSC
	SOSC	

Third Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21500	MENG 24200	MENG 24400
MENG 24100	CIV	CIV / ART
BIOS 20187		
CIV		

Fourth Year

Autumn Quarter	Winter Quarter
MENG 21800 or 21810	MENG 21900 or 21910

Chemical Engineering Track - *Four-year plan based on mathematics placement in MATH 15100.* *This example program for the Molecular Engineering major does not require completion of mathematics, chemistry, and physics sequences during a student's first year at the University. A similar four-year plan can be developed for students placed into MATH 13100.*

First Year

Autumn Quarter	Winter Quarter	Spring Quarter
MATH 15100	MATH 15200	MATH 18300
CHEM 10100	CHEM 10200	CHEM 11300
HUMA	HUMA	ART

Second Year

Autumn Quarter	Winter Quarter	Spring Quarter
MATH 18400	MATH 18500	PHYS 13300
PHYS 13100	PHYS 13200	BIOS 20186
CHEM 22000	CHEM 22100	SOSC
SOSC	SOSC	

Third Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21100	MENG 21200	MENG 21400
BIOS 20187	MENG 21300	CIV / ART
CIV	CIV	

Fourth Year

Autumn Quarter	Winter Quarter	Spring Quarter
MENG 21500	MENG 24200	MENG 24400
MENG 21800 or 21810	MENG 21900 or 21910	
MENG 24100		

Quantum Engineering Track - *Four-year plan based on mathematics placement in MATH 18300.* *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. Note that the intermediate* *electricity and magnetism courses (PHYS 22500-22700) can be moved to the third year without other adjustments to the plan outlined here.*

First Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 18300	MATH 18400	MATH 18500
CHEM 10100	CHEM 10200	CHEM 11300
PHYS 13100	PHYS 13200	PHYS 13300
HUMA	HUMA	ART
Second Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21100	MENG 21200	MENG 21400
MATH 18600	MENG 21300	PHYS 22700
SOSC	PHYS 22500	BIOS
	SOSC	SOSC
Third Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21500	MENG 26110	MENG 26200
MENG 26100	MENG elective	CIV / ART
BIOS	CIV	
CIV		
Fourth Year		
Autumn Quarter	**Winter Quarter**	
MENG 21800 or 21810	MENG 21900 or 21910	

Quantum Engineering Track - *Four-year plan based on mathematics placement in MATH 15100.* *This example program for the Molecular Engineering major does not require completion of mathematics, chemistry, and physics sequences during a student's first year at the University.*

First Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 15100	MATH 15200	MATH 18300
PHYS 13100	PHYS 13200	PHYS 13300
HUMA	HUMA	BIOS
		ART
Second Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MATH 18400	MATH 18500	MATH 18600
CHEM 10100	CHEM 10200	CHEM 11300
BIOS	SOSC	SOSC
SOSC		
Third Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21100	MENG 21200	MENG 21400
CIV	MENG 21300	MENG elective
	CIV	CIV / ART
Fourth Year		
Autumn Quarter	**Winter Quarter**	**Spring Quarter**
MENG 21500	MENG 21900 or 21910	MENG 26200
MENG 21800 or 21810	MENG 26110	PHYS 22700
MENG 26100	PHYS 22500	

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 Director of Undergraduate Studies (Mark Stoykovich, stoykovich@uchicago.edu) before the beginning of the fourth 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.

Specialized Minors in Molecular Engineering

Students majoring in Molecular Engineering or other closely related scientific disciplines can further broaden and deepen their engineering and scientific knowledge by completing specialized minors in Molecular Engineering. Seven minors composed of advanced coursework have been offered since the 2020–21 academic year in the specialized areas of Quantum Information Science; Molecular, Cellular, and Tissue Engineering; Immunoengineering; Systems Bioengineering; Molecular Science and Engineering of Polymers and Soft Materials; Molecular Engineering of Sustainable Energy and Water Resources; and Computational Molecular Engineering.

Minor Program in Quantum Information Science

Quantum science, which harnesses the strange rules of physics that govern the smallest particles in nature, is shifting paradigms in fundamental and applied physics, chemistry, biology, and computer science. The minor leverages the unique strengths of the faculties of Molecular Engineering, Physics, and Computer Science to provide students with a foundation to understand and contribute to quantum sciences and technologies. The minor focuses on both the theory of quantum information processing as well as the physical systems and principles that comprise quantum technology.

Summary of Requirements for the Minor in Quantum Information Science

One of the following:		100
MENG 26400	Quantum Computation *	
MENG 37400	Advanced Quantum Information and Computation *	
MENG 26500	Foundations of Quantum Optics	100
MENG 26600	Electronic and Quantum Materials for Technology	100
MENG 31400	Advanced Quantum Engineering	100
Two of the following:		200
MENG 26200	QuantumLab	
MENG 37100	Implementation of Quantum Information Processors	
MENG 37200	Quantum Dissipation and Quantum Measurement	
MENG 37500	Quantum Measurements and Metrology	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Minor Program in Molecular, Cellular, and Tissue Engineering

The minor in Molecular, Cellular, and Tissue Engineering provides a strong background in cell and molecular biology to allow molecular engineering innovation in the engineering areas of biomaterials, regenerative medicine, and stem cell bioengineering. Courses are offered in these basic areas as well as microfluidics, synthetic biology, molecular imaging, immunoengineering, and nanomedicine to develop novel cellular and molecular therapies. The course of study emphasizes both basic aspects of physical and cellular biology and translational applications in medicine. In addition, courses on quantitative aspects of cell biology and systems biology are offered, building upon biological fundamentals with quantitative analysis.

Summary of Requirements for the Minor in Molecular, Cellular, and Tissue Engineering

MENG 22200	Cellular Engineering *	100
MENG 22100	Quantitative Physiology	100
MENG 23100	Biological Materials	100
MENG 23110	Stem Cell Biology, Regeneration, and Disease Modeling	100
Two of the following:		200
MENG 22300	Quantitative Systems Biology	
MENG 23120	The Structural Basis of Biomolecular Engineering	
MENG 23130	Omics Technologies and Applications in Biological Systems	
MENG 23140	Biodiagnostics and Biosensors	

MENG 23150	Nanomedicine	
MENG 23500	Synthetic Biology	
MENG 23510	Microfluidics and Its Applications	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Minor Program in Immunoengineering

Immunoengineering is an emerging discipline at the intersection of engineering and immunology. Immunoengineering applies engineering principles and methods to quantitatively study and manipulate the complex immune system. It is becoming a powerful approach to understand, manipulate, stimulate, and eventually control immune molecules and cells to treat a broad range of health conditions, including cancer, infection, and autoimmunity. Immunoengineering not only drives innovation in immunological research, but also advances technological development in immunotherapies. Recent developments in immunotherapy have shifted the paradigm for cancer treatment, and immunotherapy is considered the future of disease treatment.

Summary of Requirements for the Minor in Immunoengineering

MENG 22100	Quantitative Physiology *	100
MENG 23200	Principles of Immunology	100
MENG 23300	Quantitative Immunobiology	100
MENG 23310	Immunoengineering Laboratory	100
One of the following:		100
MENG 22200	Cellular Engineering	
MENG 22300	Quantitative Systems Biology	
MENG 23100	Biological Materials	
MENG 23330	Immunogenomics II: Data Science in Systems Immunology	
MENG 23340	Engineering Immunotherapeutics	
MENG 23510	Microfluidics and Its Applications	
One of the following:		100
BIOS 25108	Cancer Biology	
BIOS 25216	Molecular Basis of Bacterial Disease	
BIOS 25258	Immunopathology	
BIOS 25260	Host Pathogen Interactions	
BIOS 25266	Molecular Immunology	
BIOS 27811	Global Health Sciences II: Microbiology	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Minor Program in Systems Bioengineering

The minor in Systems Bioengineering will provide students with strong knowledge and applied skills in the use of quantitative methods for the analysis, manipulation, and computational modeling of complex biological systems, and will introduce them to some of the most important problems and applications in quantitative and systems biology. The students will 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 and implemented in the laboratory. Quantitative experimental methods currently used in systems biology will be introduced. 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.

Summary of Requirements for the Minor in Systems Bioengineering

MENG 22300	Quantitative Systems Biology *	100
MENG 23300	Quantitative Immunobiology	100
MENG 23500	Synthetic Biology	100
Two of the following:		200
MENG 22100	Quantitative Physiology	

MENG 22200	Cellular Engineering	
MENG 23510	Microfluidics and Its Applications	
BIOS 20249	Genome Informatics: Genome Org, Expression & Transmission	
One of the following:		100
BIOS 21306	Human Genetics and Evolution	
BIOS 21360	Advanced Molecular Biology	
BIOS 23258	Molecular Evolution I: Fundamentals and Principles	
BIOS 28407	Genomics and Systems Biology	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Minor Program in Molecular Science and Engineering of Polymers and Soft Materials

The plastic in molded bottles and food packaging . . . Synthetic rubber in tires . . . Scratch-resistant coatings that are chemically and thermally stable . . . Bulletproof materials in lightweight vests . . . Super-absorbent materials such as those in diapers . . . Synthetic polymers are ubiquitous in the 21st century, with such engineered materials exhibiting unique properties and enabling novel applications relative to traditional materials. The minor in Molecular Science and Engineering of Polymers and Soft Materials is designed to prepare students to enter diverse fields in the polymer and soft material sciences. A sophisticated understanding of the molecular-level interactions and structure is required to work with polymers and ultimately provides the opportunity to predict and control material behaviors at the macroscale. Students in the minor will study the chemistry, physics, thermophysical properties, modeling, and processing of polymers, as well as other classes of soft materials including liquid crystals and colloids. Applications of polymers and soft matter in lightweight composites, smart or responsive materials, bioinspired and biomedical materials, advanced lithography, and energy-related materials will be examined.

Summary of Requirements for the Minor in Molecular Science and Engineering of Polymers and Soft Materials

MENG 21400	Molecular Engineering Thermodynamics	100
MENG 25100	Introduction to Polymer Science	100
MENG 25130	Soft Matter Characterization Laboratory	100
One of the following pairs:		200
MENG 25110 & MENG 25120	Polymer Synthesis and Polymer Physics	
MENG 25110 & CHEM 22200	Polymer Synthesis and Organic Chemistry III	
MENG 25120 & MENG 25140	Polymer Physics and Functional Polymers for Electronics, Photonics, and Energy Technology	
MENG 25120 & MENG 25500	Polymer Physics and Classical Molecular and Materials Modeling	
One of the following:		100
MENG 23100	Biological Materials	
MENG 25110	Polymer Synthesis	
MENG 25120	Polymer Physics	
MENG 25140	Functional Polymers for Electronics, Photonics, and Energy Technology	
MENG 25320	Electrochemical Principles and Methods	
MENG 25500	Classical Molecular and Materials Modeling	
MENG 25640	AI, Automation, and Autonomous Experimentation for Materials Discovery	
PHYS 36700	Soft Condensed Matter Phys	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Minor Program in Molecular Engineering of Sustainable Energy and Water Resources

Climate change and finite resources for an ever-growing global population mandate major initiatives on achieving a better and more sustainable future. Access to clean water and the development of sustainable energy technologies are at the heart of this global challenge. The minor in Molecular Engineering of Sustainable Energy and Water Resources is tailored for students interested in gaining a deeper understanding of the science, conservation, and management of energy and water resources. Concepts of emphasis include fundamental electrochemistry, materials and devices for energy conversion and storage (e.g., batteries, solar cells, wind turbines, geothermal), the molecular behavior of water, climate change and its impacts, and energy and water policy.

Summary of Requirements for the Minor in Molecular Engineering of Sustainable Energy and Water Resources

MENG 21500	Molecular Engineering Transport Phenomena *	100
MENG 25300	Molecular Science and Engineering of Water	100
MENG 25310	Energy Storage and Conversion Devices	100
One of the following:		100
MENG 25320	Electrochemical Principles and Methods	
MENG 25330	Materials and Characterization Tools to Address Challenges in Energy and Water	
Two of the following:		200
Either MENG 25320 or MENG 25330 if not selected in the category above.		
MENG 25640	AI, Automation, and Autonomous Experimentation for Materials Discovery	
MENG 35340	Photonic Materials for Energy and Sustainability	
MENG 35350	Experimental Electrochemistry Laboratory +	
CCSG 20300	The Economics of Climate Change and Energy	
ENSC 23900	Environmental Chemistry	
PBPL 22510	The Climate and Growth Challenge	
PBPL 29070	Nuclear Policy	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

\+ By instructor consent only. Limited number of seats available per year, with priority given to students in the Master of Engineering program.

Minor Program in Computational Molecular Engineering

The minor in Computational Molecular Engineering will provide students with expertise in mathematics, numerical algorithms, computational methods, and molecular and multiscale modeling techniques. The minor will introduce concepts from materials design, device design, and computational interpretation of experimental data, and provide training in tools for materials modeling ranging from electronic structure-level quantum mechanical calculations to molecular modeling methods at scales ranging from angstroms to meters.

Summary of Requirements for the Minor in Computational Molecular Engineering

MENG 21400	Molecular Engineering Thermodynamics *	100
MENG 31200	Thermodynamics and Statistical Mechanics	100
MENG 25500	Classical Molecular and Materials Modeling	100
MENG 25510	Quantum Molecular and Materials Modeling	100
One of the following:		100
MENG 23100	Biological Materials	
MENG 25100	Introduction to Polymer Science	
MENG 25120	Polymer Physics	
MENG 25640	AI, Automation, and Autonomous Experimentation for Materials Discovery	
BCMB 31358	Simulation, Modeling, and Computation in Biophysics	
PHYS 25000	Computational Physics	
One of the following:		100
CMSC 25025	Machine Learning and Large-Scale Data Analysis	
CMSC 25300	Mathematical Foundations of Machine Learning	
CMSC 25400	Machine Learning	
CMSC 25500	Introduction to Neural Networks	
CMSC 23710	Scientific Visualization	
CMSC 23900	Data Visualization	
TTIC 31020	Introduction to Machine Learning	
Total Units		600

* For students majoring in Molecular Engineering, this course must be taken as an elective within the major and will not be counted toward minor totals. No substitution is required.

Additional Requirements for Minoring in Molecular Engineering

Before a student can declare a minor in Molecular Engineering, the student must complete the general education requirements in mathematics, physical sciences, and biological sciences. Following completion of these requirements, students can contact the Director of Undergraduate Studies for Molecular Engineering, Mark Stoykovich (stoykovich@uchicago.edu), to plan a course of study for the minor program and/or receive approval of their minor program on a Consent to Complete a Minor Program (http://collegecatalog.uchicago.edu/thecollege/minors/Consent_Minor_Program.pdf) form. The signed Consent to Complete a Minor Program 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.

Additional Minors in Molecular Engineering

For those students not majoring in Molecular Engineering or a related field, the College offers two additional minors in Molecular Engineering. The minors complement various major programs and better prepare students for STEM fields, equipping each with basic engineering tools to discover new ways to think about cutting-edge technologies and problem solving.

Minor Program in Molecular Engineering

The minor in Molecular Engineering introduces the technical fundamentals of molecular engineering, including in quantum mechanics, molecular thermodynamics, transport phenomena, and the application of such concepts to advanced technologies. Primarily targeted to students majoring in the physical or biological sciences, this minor provides a strong preparation for careers or postgraduate studies in engineering fields.

Summary of Requirements for the Minor in Molecular Engineering

MENG 21100	Principles of Engineering Analysis I	100
MENG 21200	Principles of Engineering Analysis II	100
Two to four of the following:		200-400
MENG 21300	Engineering Quantum Mechanics	
MENG 21400	Molecular Engineering Thermodynamics	
MENG 21500	Molecular Engineering Transport Phenomena	
MENG 24100	Molecular Engineering Thermodynamics of Phase Equilibria	
MENG 24200	Molecular Transport Phenomena II: Fluid Flow and Convective Transport Processes	
MENG 26100	Intermediate Quantum Engineering	
Zero to two of the following:		000-200
Advanced electives in MENG (courses numbered 22000 or higher)		
Advanced electives selected in consultation with the Director of Undergraduate Studies *		
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 minor in Molecular Engineering Technology and Innovation is intended for students majoring in economics, business, policy, or related fields, and presents basic engineering concepts as they relate to evolving technologies, scientific innovation and entrepreneurship, scientific policy, and the broader impacts of engineering in society.

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

MENG 20000	Introduction to Emerging Technologies	100
MENG 20100	Engineering Design Principles and Practice for Everyone	100
MENG 20400	Commercializing Products with Molecular Engineering	100
Three elective courses selected in consultation with the Director of Undergraduate Studies [1,2,3]		300
Total Units		600

1 MENG 15100 Machine Learning and Artificial Intelligence for Molecular Discovery and Engineering, MENG 15200 Engineering for Human Health, and MENG 15300 Energy Matters - From Mine to Line are highly recommended additions to the MENG minor in Technology and Innovation. Courses in the minor program may not be counted toward the general education requirements.

2 All courses in Molecular Engineering are pre-approved as electives for the minor, with courses such as MENG 30500 Responsible and Effective Technology Management, MENG 23150 Nanomedicine, MENG 26400 Quantum Computation, and MENG 26630 Introduction to Nanofabrication being especially recommended. Accessibility to MENG courses is dictated by the individual course prerequisites, and students who meet the listed prerequisites are welcome to take any MENG course. MENG courses therefore may be more or less accessible depending on a student's primary major and background.

3 The following courses are also pre-approved for the minor: BIOS 11140, BUSN 20330, BUSN 20340, ENSC 21100, ENSC 23900, HIPS 17502, PBPL 23100, PBPL 24701, PHSC 12400, and 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.

Minor Program Requirements for Molecular Engineering and Molecular Engineering Technology and Innovation

Before a student can declare a minor in Molecular Engineering, the student must complete the general education requirements in mathematics, physical sciences, and biological sciences. Following completion of these requirements, students can contact the Director of Undergraduate Studies for Molecular Engineering, Mark Stoykovich (stoykovich@uchicago.edu), to plan a course of study for the minor program and/or receive approval of their minor program on a Consent to Complete a Minor Program (http://collegecatalog.uchicago.edu/thecollege/minors/Consent_Minor_Program.pdf) form. The signed Consent to Complete a Minor Program 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.

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.

Molecular Engineering Courses

MENG 00211. Collaborative Learning in Molecular Engineering (CLIME) for Principles of Engineering Analysis. 000 Units.
This optional workshop is for students who are concurrently enrolled in MENG 21100 Principles of Engineering Analysis I. CLIME for MENG 21100 provides students with an in-depth and applied understanding of foundational engineering concepts through weekly problem sessions that augment the MENG 21100 course. Sessions consist of active small group discussions, in a collaborative environment fostered by undergraduate team leaders, and rigorous problem sets designed to develop analytical intuition and critical thinking skills. Success in CLIME is primarily achieved through consistent engagement. Therefore, grades in this zero-credit course are assigned P/F based on student attendance and level of participation.

MENG 00213. Collaborative Learning in Molecular Engineering (CLIME) for Engineering Quantum Mechanics. 000 Units.
This optional workshop is for students who are concurrently enrolled in MENG 21300 Engineering Quantum Mechanics. CLIME for MENG 21300 provides students with fundamental quantum mechanics concepts, with an emphasis on their mathematical application, through weekly problem sessions that augment the MENG 21300 course. Sessions consist of active small group discussions, in a collaborative environment fostered by undergraduate team leaders, and rigorous problem sets designed to develop analytical intuition and critical thinking skills. Success in CLIME is primarily achieved through consistent engagement. Therefore, grades in this zero-credit course are assigned P/F based on student attendance and level of participation.

MENG 00214. Collaborative Learning in Molecular Engineering (CLIME) for Molecular Engineering Thermodynamics. 000 Units.
This optional workshop is for students who are concurrently enrolled in MENG 21400 Molecular Engineering Thermodynamics. CLIME for MENG 21400 provides students with fundamental thermodynamics concepts, with an emphasis on their mathematical implementation and engineering applications, through weekly problem sessions that augment the MENG 21400 course. Sessions consist of active small group discussions, in a collaborative environment fostered by undergraduate team leaders, and rigorous problem sets designed to develop analytical intuition and critical thinking skills. Success in CLIME is primarily achieved through consistent engagement. Therefore, grades in this zero-credit course are assigned P/F based on student attendance and level of participation.

MENG 15100. Machine Learning and Artificial Intelligence for Molecular Discovery and Engineering. 100 Units.
The foundations of artificial intelligence can be dated back to Alan Turing's seminal 1950 paper in which the concept of "thinking machines" was first introduced and the 1956 Dartmouth Summer Conference in which the term artificial intelligence was first coined. The field has since passed through multiple epochs of development, and today artificial intelligence and machine learning are ubiquitous and enabling tools that pervade all corners of engineering discovery and practice. This course will survey the conceptual and historical basis of artificial intelligence and machine learning; the role, integration, and ethics of these approaches in modern engineering practice; the mathematical and algorithmic underpinnings of some popular machine learning techniques;

and selected applications of these tools in particular applications in molecular engineering drawn from areas such as energy and sustainability, drug discovery, quantum science and information, materials science, and bioengineering.
Instructor(s): Andrew Ferguson Terms Offered: Autumn
Prerequisite(s): Quantitative analysis and numerical calculations will be an important part of the course, but mathematics beyond algebra will not be required and any necessary mathematics will be reviewed as part of the course.
Equivalent Course(s): PHSC 15100

MENG 15200. Engineering for Human Health. 100 Units.
This course is designed to introduce undergraduates to the types of clinical problems that engineers solve and the physical concepts they apply to solve them. Various types of devices - from genetically engineered bacteria to biosensors - will be discussed, and we will explore the physics and chemistry necessary to understand and design each of these devices. We will also discuss many of the more practical concerns that influence the development of therapies, including intellectual property, regulation, and clinical trial design. In addition, students will learn how to work effectively in groups and to communicate their findings in a professional manner.
Instructor(s): Terry Johnson Terms Offered: Winter
Equivalent Course(s): PHSC 15200

MENG 15300. Energy Matters - From Mine to Line. 100 Units.
Conversion of raw materials into usable energy and storage of the energy produced are common aspects of everyday life. The development of new materials to improve upon current capabilities is a key technological challenge of the 21st century. This course examines the key aspects for energy production, storage and conversion in existing and future power systems, including steam engine, gas turbine, solar, wind, nuclear, hydro, battery, compressed air, fuel cells etc. These technologies will be evaluated from a unique perspective from the mining (drilling) to production to utilization to recycling.
Instructor(s): Ying Shirley Meng Terms Offered: Spring

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): Terry Johnson Terms Offered: Autumn
Prerequisite(s): Completion of the general education requirements in mathematics and physical or biological sciences
Note(s): May not be counted toward PME doctoral in-depth course requirements.
Equivalent Course(s): MENG 30000

MENG 20100. Engineering Design Principles and Practice for Everyone. 100 Units.
Design concepts underpin almost every product, software, and institution we interact with daily. Many students lack a fundamental understanding of the principles of design which result in how modern products, ideas, and tools are developed. This is an introductory course, which seeks to introduce students to design in theory and practice. It examines the process of applying engineering principles to the iterative design loop and how these are implemented in practice. Emphasis is placed on the practice of design through a selected project and working with a team to achieve specific design specifications or goals. The course emphasizes iterative problem solving, design, team-oriented projects, and the soft skills that accompany their successful implementation.
Instructor(s): Aaron Esser-Kahn Terms Offered: Winter
Prerequisite(s): MENG 20000, and Completion of the general education requirements in mathematics and physical or biological sciences.

MENG 20210. The Material Science of Art-Suzanne Deal Booth Conservation Seminar. 100 Units.
This course will introduce students to the methods, theories, and strategies of scientific approaches to the study of art objects and will consider the meaning of different materials and surfaces across artistic media. It will showcase new scholarship in the fields of heritage science and object-driven art history, drawing strength from collaborative work among scientists, conservators, art historians, and curators. Heritage science draws on the applied sciences and engineering to understand how to preserve the world's cultural heritage and forge connections between making and meaning. The course will explore scientific methods for investigating the production and use of art objects. Focusing on the material studies of paintings and sculptures, pigments, and their binding media, students will learn about the material makeup of art objects. Readings will be drawn from a variety of disciplines, including material science and chemistry, art history, visual and material culture, anthropology, and philosophy.
Instructor(s): M. Kokkori Terms Offered: Spring
Prerequisite(s): This course fulfills the following requirements in the ARTH major and minor: Theory and Methodology.
Equivalent Course(s): ARTH 37800, MENG 30210, ARTH 27800

MENG 20400. Commercializing Products with Molecular Engineering. 100 Units.
Many technologies and products that have been successfully commercialized benefit from engineering at the molecular scale. This course will present case studies of such technologies and products, including those drawn from the fields of pharmaceuticals (e.g., biologics, nanoparticle-based drugs, and excipients for enhanced drug solubility), food products (e.g., Cavamax by Wacker Chemie that applies beta-cyclodextrin for molecular encapsulation to improve flavor solubility), and industrial products (e.g., Febreze Air freshener, sunscreens with UV protection, photographic films, and slurries for polishing surfaces). Each case study will examine: the unmet market need addressed by the product, the science behind the molecular engineering of the technology, the background/history of the technology, and key attributes/decisions made by inventors along the pathway to commercialization. Upon completion of the course, students will be able to understand the overall process for developing a new technology/product, outline the steps to design the key critical-to-quality (CTQ) attributes, describe how to monetize a technology/product, and recognize the avenues available to protect the technology/product or create barriers to entry to the market.
Instructor(s): Atul Khare, Kathleen Akers Terms Offered: Spring
Prerequisite(s): MENG 20000 or MENG 21100
Note(s): May not be counted toward PME doctoral in-depth course requirements.
Equivalent Course(s): MENG 30400

MENG 21100-21200. Principles of Engineering Analysis I and II.
The courses in Engineering Analysis provide a foundation for engineering problem solving and quantitative analysis. Skills in developing mathematical models that describe biological, chemical, or physical systems will be acquired, including defining the system and system boundaries, simplifying complex systems through the application and justification of engineering assumptions, and implementing engineering data. Applied mathematical and computational tools to solve such models will be introduced. Also emphasized will be the topics of dimensions and units, scaling analyses, and data representation and visualization.

MENG 21100. Principles of Engineering Analysis I. 100 Units.
The first quarter of Engineering Analysis introduces engineering students to the derivation and solution of balance equations for extensive properties such as mass, energy, momentum, and charge in a system. Students will develop algebraic, differential, and integral balances for continuous, transient and steady-state processes. Material balances will be considered for systems with multiple inlets/outlets and with recycle, multicomponent mixtures, and systems with phase changes and chemical reactions. Energy balances in open and closed steady-state systems will be introduced, as will mechanical energy and momentum balances of importance in the flow of fluids in the derivation and application of Bernoulli's equation. Skills in basic structured programming and data visualization in Python will be acquired, and simple algorithm development will be emphasized for numerical methods such as root finding.
Instructor(s): Mark Stoykovich Terms Offered: Autumn
Prerequisite(s): PHYS 13300 or PHYS 14300, and CHEM 11300 or CHEM 12300

MENG 21200. Principles of Engineering Analysis II. 100 Units.
The second quarter of Engineering Analysis considers advanced energy balances for isothermal and adiabatic processes, systems with chemical reactions and phase changes, and systems under non-steady state conditions. In addition, the conservation of charge, Kirchhoff's current and voltage laws, and dynamic systems of charge and electrical energy will be discussed. Throughout the course, students will learn advanced numerical and computational methods in Python for solving systems of linear and non-linear equations, general minimization techniques, optimization strategies, and regression analysis. Numerical integration including the Euler and Runge-Kutta methods, as well as methods for solving ODEs (i.e., initial value problems and boundary value problems), will also be introduced.
Instructor(s): Mark Stoykovich Terms Offered: Winter
Prerequisite(s): MENG 21100 and MATH 18500

MENG 21300. Engineering Quantum Mechanics. 100 Units.
Quantum mechanics is a fundamental physical theory describing the behavior of systems on small length scales, and underlies a variety of basic phenomena in physics, chemistry and biology. It also is the basis of some of the most revolutionary technologies of the 20th century (e.g., the transistor and the laser), and will likely form the basis of even more radical quantum technologies. This course will provide students with a broad introduction to quantum mechanics, and will emphasize both a qualitative and quantitative appreciation of many of its main principles and its relevance to technology and engineering. Topics to be covered include the quantization of light and atomic orbitals, wavefunctions and probability amplitudes, the Schrodinger equation, and the basic quantum mechanics of atoms and molecules. A basic introduction to quantum bits and quantum information technology will also be provided.
Instructor(s): Peter Maurer Terms Offered: Winter
Prerequisite(s): PHYS 13300 or 14300, AND MATH 18500

MENG 21400. Molecular Engineering Thermodynamics. 100 Units.
Molecular thermodynamics integrates concepts from classical thermodynamics, statistical mechanics, and chemical physics to describe the properties of matter and behavior of systems at equilibrium. This course introduces thermodynamics for molecular engineers starting with the postulates of thermodynamics and the thermodynamic properties of pure substances. The concept of thermodynamic stability and the molecular

origins of phase transitions will be developed to predict the phase diagrams of pure substances. Engineering applications relying on thermodynamic cycles involving flow or phase changes, including engines, heat pumps, and refrigeration, will be analyzed. Finally, an introduction to statistical thermodynamics will be provided to establish the relationship between intermolecular forces and macroscopic properties through the definition of ensembles, probability distribution functions, and partition functions, as well as the consideration of fluctuations in thermodynamic variables.
Instructor(s): Chong Liu, Allison Squires Terms Offered: Spring
Prerequisite(s): MENG 21300

MENG 21500. Molecular Engineering Transport Phenomena. 100 Units.
This course introduces students to continuum mechanics, with a focus on energy and mass balances. Starting with an overview of the physical and mathematical basis of diffusion, the course will cover definitions of flux of heat and mass, setting up differential equations and boundary conditions that describe mass and energy transport, scaling and nondimensional analysis, and solution methods for common types of problems including unsteady-state problems and systems with chemical reactions.
Instructor(s): Melody Swartz Terms Offered: Autumn
Prerequisite(s): MENG 21100-21200

MENG 21800-21900. Engineering Design.
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 bioengineering, chemical and materials engineering, and quantum engineering 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. Students are required to take both MENG 21800 and 21900 in consecutive quarters given the continuity of the projects and teamwork throughout the Engineering Design sequence.

MENG 21800. Engineering Design I. 100 Units.
First quarter of Engineering Design.
Instructor(s): Mark Stoykovich, Xiaoying Liu, Mustafa Guler, Terry Johnson Terms Offered: Autumn
Prerequisite(s): Instructor consent required

MENG 21900. Engineering Design II. 100 Units.
Second quarter of Engineering Design.
Instructor(s): Mark Stoykovich, Xiaoying Liu, Mustafa Guler, Terry Johnson Terms Offered: Winter
Prerequisite(s): MENG 21800

MENG 21810-21910. Engineering Research: Strategies and Tactics.
The research endeavor in engineering and the sciences benefits greatly from the judicious application of strategies and tactics that enhance productivity and impact. The engineering research courses will introduce how to create a long-term plan that outlines a project's direction or goals (i.e., the strategy) and how to operate in the laboratory on a daily basis to achieve those goals (i.e., the tactics). Emphasis will be placed on enhancing skills to communicate project plans and results clearly and concisely to various audiences; define project timelines; access and manage resources to achieve objectives; work as part of a team; and engage with collaborators, the scientific community, and society. The strategies and tactics gained will be put into practice on each students' independent research projects. Students must therefore arrange an undergraduate research opportunity and project prior to the start of MENG 21810 (it is the student's responsibility and projects will not be identified or assigned by the course instructor). Continuing projects, or new projects starting concurrently with MENG 21810, will be equally suitable. Projects outside of the Pritzker School of Molecular Engineering may be appropriate but must include some aspect of molecular engineering aligned with the fields of bioengineering, chemical and materials engineering, or quantum engineering. Questions on the suitableness of projects should be directed to the course instructor.

MENG 21810. Engineering Research: Strategies and Tactics I. 100 Units.
First quarter of Engineering Research: Strategies and Tactics.
Instructor(s): Mark Stoykovich Terms Offered: Autumn. Students are required to take MENG 21810 and 21910 in consecutive quarters.
Prerequisite(s): Instructor consent required

MENG 21910. Engineering Research: Strategies and Tactics II. 100 Units.
Second quarter of Engineering Research: Strategies and Tactics.
Instructor(s): Mark Stoykovich Terms Offered: Winter. Students are required to take MENG 21810 and 21910 in consecutive quarters.
Prerequisite(s): MENG 21810

MENG 22100. Quantitative Physiology. 100 Units.
This course will address the physical principles that govern physiological and biological functions at the organ, tissue, and cellular levels through quantitative models. At the organ and tissue levels, topics will include the cardiovascular and pulmonary systems (organ function, oxygen transport, hemorheology, interstitial and lymphatic transport), skeletal mechanics, and physiology of the kidney, intestine, and liver, as well as tumor physiology. At the cellular level, topics of membrane transport, adhesion and migration mechanics; and cytokine and chemokine signaling will be addressed.
Instructor(s): Melody Swartz, Huanhuan Chen Terms Offered: Spring
Prerequisite(s): BIOS 20186 and BIOS 20187, or BIOS 20234 and BIOS 20235

MENG 22200. 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: Autumn
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence including cell and molecular biology and genetics.
Equivalent Course(s): BIOS 21508, MENG 32200, MOMN 34310

MENG 22300. 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 three quarters of a Biological Sciences Fundamentals Sequence
Equivalent Course(s): BIOS 28411, MENG 32300

MENG 23000. Experimental Bioengineering Laboratory. 100 Units.
This course provides a broad knowledge and hands-on experience in bioengineering and biomaterials. The topics to be covered include the design and characterization of materials for biomaterials, cellular engineering, nanomedicine, synthetic vaccines, immunotherapies, drug delivery, tissue engineering, bioimaging, biodiagnostics and biosensors. This course also includes experimental modules for hands-on experience relevant to the topics discussed in the lectures. Students will develop skills and experience relevant to methodologies in bioengineering research. Chromatography, spectroscopy, mechanical testing, particle size analysis, and protein activity assays will be utilized in the laboratory. Students will learn to apply knowledge of bioengineering research tools to design and conduct bioengineering experiments for which they will analyze, interpret, and present the experimental results.
Instructor(s): Mustafa Guler Terms Offered: Spring
Prerequisite(s): MENG 23100 or MENG 23150
Equivalent Course(s): MENG 33000

MENG 23100. 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.
Terms Offered: Autumn. Will not be offered in 2025/26 academic year.
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): MENG 33100

MENG 23110. Stem Cell Biology, Regeneration, and Disease Modeling. 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): Huanhuan Chen Terms Offered: Autumn
Prerequisite(s): BIOS 20186 or BIOS 20234
Equivalent Course(s): MENG 33110, BIOS 21507, MPMM 34300

MENG 23120. The Structural Basis of Biomolecular Engineering. 100 Units.
In this highly practical course, students will learn different approaches to interrogate the structure-function relationship of proteins. Essential skills in identifying related protein sequences, performing multiple sequence alignments, and visualizing and interpreting conservation in the context of available structures will be acquired. The most basic method of biomolecular engineering is based on rationale design which uses such knowledge of sequence and structure to predict or explore changes in function in a low throughput manner. Advanced methods that employ evolutionary platforms, such as phage-, ribosome-, and yeast display, will also be introduced for screening large libraries of biomolecules to find variants with a specific function of interest. Additional biomolecular engineering topics to be covered may include computational tools to model and design proteins, protein fusions, enzymatic or chemical modifications to change function, and pharmacokinetics. Students will be assessed through in-class discussion, take-home assignments, exams, and an end-of-term project chosen by the student with approval from the instructor(s).
Instructor(s): Juan Mendoza Terms Offered: Spring
Prerequisite(s): BIOS 20200
Equivalent Course(s): MENG 33120

MENG 23130. Omics Technologies and Applications in Biological Systems. 100 Units.
Modern genomic and proteomic technologies are transforming the analysis and engineering of biological systems. One part of the course will introduce the molecular biology of genomics, including how and why next-generation sequencing is used to measure DNA, RNA, and epigenetic patterns. In addition to experimental tools, it will cover key computational concepts for transforming raw genomic data into biologically meaningful data, as well as the application of those results to analyze biological systems. Specific topics will vary but will include single-cell RNA-sequencing and its analysis in different settings. The other part of the course will focus on technologies that enable the identification of proteins and their dysregulation in disease. Examples include mass spectrometry techniques to determine the exact number of proteins in cells, as well as techniques that identify the types and locations of post-translational protein modifications, such as histone methylation, that are frequently associated with diseases such as cancer. Additionally, the course will review methods to discover protein-protein interactions using computational and experimental screening methods. Student assessments will be made through in-class discussion, take-home assignments, exams, and an end-of-term project chosen by the student with approval from the instructor(s).
Instructor(s): Samantha Riesenfeld Terms Offered: Autumn
Prerequisite(s): BIOS 20200 or equivalent, and experience with data analysis and computation in R or Python (e.g., MENG 26030, BIOS 20151/20152, STAT/CMSC 11800, or STAT 22000).
Equivalent Course(s): MENG 33130

MENG 23150. 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 33150

MENG 23200. Principles of Immunology. 100 Units.
In this course students will gain a comprehensive understanding of the essential principles of immunology. The course will introduce the concept of innate immunity and pattern recognition and how antigen is processed for presentation to the immune system. We will examine how antigen presentation links innate and adaptive immunity. We will then discuss the two arms of adaptive immunity (humoral and cellular) in detail from their development to effector stages. In the last section of the course we will discuss some key aspects of immune system function including immunological memory and vaccination, immunological tolerance and its failure (autoimmunity/allergy), and mucosal immunology and the microbiome. Students will present primary articles related to the topics discussed in class in a weekly discussion section. The course will be graded on class participation, quizzes, a midterm, and a final essay-based exam.
Instructor(s): Cathryn Nagler Terms Offered: Autumn

Prerequisite(s): BIOS 20186 or BIOS 20234 (or equivalent undergraduate coursework with the permission of the instructor)
Equivalent Course(s): MENG 33200

MENG 23210. Fundamentals and Applications of the Human Microbiota. 100 Units.
Thousands of microbes colonize the human body to collectively establish the human microbiota. Research findings over the past two decades have led to a growing appreciation of the importance of the microbiota in various facets of human health. This course will explore the human microbiota through a critical review of the primary scientific literature. The first portion of the course will cover distinct ways by which the human microbiota impacts mammalian health. The second part of the course will focus on established and developing microbiota-targeting biotechnologies. Students will leave the course with a general understanding of the current state of human microbiota research and its therapeutic and diagnostic applications.
Instructor(s): S. Light, M. Mimee Terms Offered: Winter
Prerequisite(s): Three quarters of a Biological Sciences Fundamentals Sequence. Third or fourth year standing or consent of instructor.
Note(s): GP.
Equivalent Course(s): BIOS 25207, MENG 33210, MICR 38000

MENG 23300. 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).
Note(s): CB. GP.
Equivalent Course(s): IMMU 34800, MENG 33300, BIOS 26403

MENG 23310. Immunoengineering Laboratory. 100 Units.
The goal of this laboratory course is to provide students with an original and hands-on research experience in the fields of immunoengineering and synthetic immunology, whereby new molecules will be designed and tested by students in the lab to probe or control immune processes. Specifically, students will study how newly discovered cancer vaccines work. The course will cover wet lab techniques to manipulate and analyze DNA, proteins, and cells, including next-generation sequencing, genome editing, cellular imaging, and nanobodies. In addition, computational tools will be used for processing and analyzing the data generated by students during class. The outcome of students' research during this class will help decipher the inner workings of successful anti-tumor vaccines, which is important to inform future cancer immunotherapies
Instructor(s): Nicolas Chevrier Terms Offered: Winter
Prerequisite(s): Completion of the first two quarters of a Biological Sciences Fundamentals Sequence. Prior molecular and cellular biology wet lab work experience is an advantage but not required.
Equivalent Course(s): MENG 33310

MENG 23330. Immunogenomics II: Data Science in Systems Immunology. 100 Units.
This course presents essential concepts in genomic data science and trains students to apply the concepts in immunological contexts. The course encourages students to think independently about genomic analyses. Students will gain an understanding of how to use basic statistics, linear algebra, and computation to explore, analyze, and interpret published RNA-sequencing data (bulk and single-cell) and immune-cell receptor sequencing data. Student performance will be assessed through in-class discussions, take-home assignments and exams, and an end-of-term final project of the student's choice.
Instructor(s): Samantha Riesenfeld, Joshua Weinstein Terms Offered: Winter
Prerequisite(s): Basic programming skills in R or Python, including control structures, data loading and saving, creating basic plots, and working with data frames. Basic molecular biology, including the central dogma.
Note(s): This course is required for, but not limited to, the Computational and Systems Immunology PhD track in Immunology.
Equivalent Course(s): IMMU 48900, MENG 33330

MENG 23340. Engineering Immunotherapeutics. 100 Units.
Engineering Immunotherapeutics
Instructor(s): Cathryn Nagler Terms Offered: Spring

Prerequisite(s): Two quarters of a Biological Sciences fundamental sequence, undergraduate third- or fourth-year standing, or permission of the instructor. Knowledge of fundamental concepts of innate and adaptive immunity from prior course work is required. The detailed molecular understanding of immunology covered in MENG 23200/33200 is not required.
Equivalent Course(s): MENG 33340

MENG 23500. 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 21500, BIOS 20236, and BIOS 20200 are recommended but not required.
Equivalent Course(s): MENG 33500

MENG 23510. 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. Will not be offered in 2025/26 academic year.
Prerequisite(s): MATH 13300 (or higher), or MATH 13200 (or higher) plus BIOS 20151 or BIOS 20152 or BIOS 20236
Equivalent Course(s): MENG 33510

MENG 24100. Molecular Engineering Thermodynamics of Phase Equilibria. 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 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): Chibueze Amanchukwu Terms Offered: Autumn
Prerequisite(s): MENG 21400 or CHEM 26200 or PHYS 27900

MENG 24200. Molecular Transport Phenomena II: Fluid Flow and Convective Transport Processes. 100 Units.
This course will cover topics related to fluid flow and convective mass and heat transport relevant to describing chemical and biological systems. First, students learn how bulk fluid flow (velocity) is related to the transport of momentum through the application of the Navier-Stokes equation and boundary conditions. Second, fluid flow is described to understand the role of viscous forces on the formation of boundary layers near surfaces. The primary focus is on the laminar flow of Newtonian fluids, but relevant conditions leading to turbulent flow are touched upon. Standard examples such as Poiseuille flow, falling films, and flow around a sphere are covered. Third, the concepts of bulk fluid flow and boundary layer are extended to describe convective mass (concentration) and heat (temperature) transport processes. Students learn how fluid motion contributes to the flux of chemical species and the transfer of heat. Lastly, the course has a laboratory component that reinforces fundamental concepts covered in the lectures. Laboratory exercises include measurement of viscosity, Hagen-Poiseuille flow in tubes, and fabrication and assembly of microfluidic devices.
Instructor(s): Shrayesh Patel Terms Offered: Winter
Prerequisite(s): MENG 21500

MENG 24400. 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 21400 (or CHEM 26200 or PHYS 27900) and MENG 21500

MENG 25100. 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 Terms Offered: Autumn
Prerequisite(s): MENG 21400 or CHEM 26200 or PHYS 27900
Equivalent Course(s): MENG 35100

MENG 25110. 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 35110, CHEM 39100

MENG 25120. 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: Spring
Prerequisite(s): MENG 25100
Equivalent Course(s): MENG 35120

MENG 25130. Soft Matter Characterization Laboratory. 100 Units.
The goal of this course is to train students in the fundamental experimental approaches to polymer and soft materials characterization. The course will cover both the theory and practice of techniques focused on three themes: molar mass determination (size exclusion chromatography, laser light scattering, NMR spectroscopy); morphology and structure (x-ray scattering, electron microscopy, atomic force microscopy); and thermo-mechanical properties (calorimetry, thermogravimetry, dynamic mechanical analysis, rheometry, tensile testing). Contextual application of these characterization techniques to modern research problems will be introduced. Through this course, students will develop foundational experimental skills necessary for addressing research challenges in modern polymer and soft materials science and engineering.
Instructor(s): Philip Griffin Terms Offered: Winter
Prerequisite(s): MENG 25100
Equivalent Course(s): MENG 35130

MENG 25140. Functional Polymers for Electronics, Photonics, and Energy Technology. 100 Units.
In this course, students will learn the fundamental principles of the functional properties of polymers that enable their use in electronics, photonics and energy technology. The topics mainly include electron and ion transport properties, relationships between chemical structures and energy band structures, photo-excitation properties, luminescent properties, thermoelectric property, ferroelectric and ferromagnetic properties, as well as the associated device categories of organic field-effect transistors, organic light-emitting diodes, lasers, electrochromic devices, photovoltaic cells, and photodetectors.
Instructor(s): Sihong Wang Terms Offered: Winter
Prerequisite(s): MENG 25100 (or MENG 35100), AND CHEM 22000 and CHEM 22100
Equivalent Course(s): MENG 35140

MENG 25300. 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): Chong Liu Terms Offered: Autumn
Prerequisite(s): MENG 21400 or CHEM 26200 or PHYS 27900 (or concurrent)

Equivalent Course(s): MENG 35300

MENG 25310. Energy Storage and Conversion Devices. 100 Units.
Addressing the challenges of a sustainable energy future requires a foundational knowledge of current and emerging energy conversion and storage technologies. Energy conversion devices such as solar cells and fuel cells to energy storage systems such as lithium-ion batteries and redox-flow batteries will be covered. Devices related to carbon capture and conversion in addition to 'green fuels' will be introduced as well. Applying basic principles of chemistry, thermodynamics, and transport phenomena, this course will provide a deep understanding of the operational mechanisms, resources, and material properties of each device and the synergies between them.
Instructor(s): Chibueze Amanchukwu Terms Offered: Winter
Prerequisite(s): MENG 21400 (or CHEM 26200 or PHYS 27900) AND MENG 21500
Equivalent Course(s): MENG 35310

MENG 25320. 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 21400 (or CHEM 26200 or PHYS 27900) and MENG 21500
Equivalent Course(s): MENG 35320

MENG 25330. Materials and Characterization Tools to Address Challenges in Energy and Water. 100 Units.
The development of new materials, as well as understanding the materials' structure and dynamics, are at the heart of addressing the challenges in energy and water technologies. This course will introduce students to the design and development of advanced functional materials that enable energy and water related technologies. The importance of all classes of materials spanning metals, alloys, ceramics, polymers, glasses, and their combinations as composite materials will be covered. To understand material properties and function, students will learn about essential characterization tools including microscopy, spectroscopy and mechanical testing techniques. In addition, the course will convey the importance of advanced characterization tools available at X-ray and neutron facilities that are essential in revealing unique physical properties.
Instructor(s): Junhong Chen Terms Offered: Winter. Offered in alternating academic years. Will not be offered in 2026/27 academic year.
Prerequisite(s): MENG 21400 (or CHEM 26200 or PHYS 27900)
Equivalent Course(s): MENG 35330

MENG 25500. Classical Molecular and Materials Modeling. 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 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. Students will also establish expertise in scientific programming in Python 3.
Instructor(s): Andrew Ferguson Terms Offered: Winter
Prerequisite(s): MENG 21400 (or CHEM 26200 or PHYS 27900) and MATH 18500. MENG 21200, or prior course work or research experience with elementary programming, is strongly recommended.
Equivalent Course(s): MENG 35500

MENG 25510. Quantum Molecular and Materials Modeling. 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): Laura Gagliardi, Giulia Galli Terms Offered: Spring
Prerequisite(s): MENG 26100, PHYS 23510, CHEM 26100, or instructor consent
Equivalent Course(s): CHEM 36800, CHEM 26800, MENG 35510

MENG 25640. AI, Automation, and Autonomous Experimentation for Materials Discovery. 100 Units.
This course introduces students to the principles and practice of AI-guided, automated, and autonomous experimentation for materials discovery. As materials research faces urgent challenges in sustainability, energy, and health, traditional trial-and-error approaches are often too slow and inefficient. Advances in laboratory automation, data-driven decision-making, and closed-loop experimentation provide new ways to explore

experimental spaces more systematically, efficiently, and reproducibly. The course teaches the core foundations and practical toolbox for AI-driven experimentation, including laboratory automation, integration, design of experiments, representation of experiments and data, and AI/ML methods for experimental decision-making. Representative case studies drawn from molecular engineering, spanning polymers, chemistry, energy materials, and characterization workflows, are used to guide students through real AI-enabled experimental scenarios. Rather than focusing on building robotic systems or developing new machine learning architectures, the course emphasizes experimental judgment, decision logic, and effective human-in-the-loop control in AI-driven automated workflows for materials discovery.
Instructor(s): Jie Xu Terms Offered: Spring
Prerequisite(s): Familiarity with basic machine learning concepts is helpful but not required. All necessary concepts will be introduced at a practical, application-oriented level. No prior programming experience is required. Hands-on components use guided notebooks with pre-written code, with emphasis on experimental reasoning and decision-making.
Equivalent Course(s): MENG 35640

MENG 26100-26110. Intermediate Quantum Engineering I-II.
This sequence of courses on quantum engineering provide an introduction to the formalism of quantum mechanics as relevant to quantum engineering and information applications, as well as advanced topics in quantum chemistry and materials modeling.

MENG 26100. Intermediate Quantum Engineering. 100 Units.
This course will provide an introduction to the formalism of quantum mechanics as relevant to quantum engineering and information applications. The emphasis will be on Hilbert space, operators and eigenstates, as applied to a variety of systems. Topics to be covered include the quantum harmonic oscillator, angular momentum, spin, and time-independent perturbation theory. Applications to quantum information processing and materials physics will be stressed.
Instructor(s): Liang Jiang Terms Offered: Autumn
Prerequisite(s): MENG 21300, MATH 18600

MENG 26110. Intermediate Quantum Engineering II. 100 Units.
This course will discuss more advanced topics in quantum engineering and quantum chemistry. Topics to be covered include identical particles, second quantization, the variational principle, time-dependent perturbation theory, the Born-Oppenheimer approximation, and the Hartree-Fock method. The course will also introduce the basic principles of quantum mechanical materials modeling, including methods that utilize quantum processors.
Instructor(s): Ruben Verresen Terms Offered: Winter
Prerequisite(s): MENG 26100, MATH 18600

MENG 26200. QuantumLab. 100 Units.
The QuantumLab course is an advanced laboratory course where students gain experience in a broad range of quantum technologies and instrumentation. The experiments reflect current research directions of quantum science and the University of Chicago's quantum program. Students will perform these experiments in small groups and study quantum effects in different quantum systems, including photons, cold atoms, quantum circuits and materials, and defect-centers. Furthermore, participants will acquire experience in instrumentation, electronics, optics, data taking and analysis.
Instructor(s): Alex High Terms Offered: Autumn Spring Winter
Prerequisite(s): MENG 21300 or PHYS 23410 or CHEM 26100
Equivalent Course(s): MENG 36200

MENG 26400. 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 linear algebra is expected, including matrix multiplication, matrix inversion, and eigenvector-eigenvalue problems. 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): MATH 18500 or MATH 19620 or equivalent
Equivalent Course(s): MENG 36400

MENG 26500. 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): MENG 21300 and MENG 26100, or PHYS 23410-23510, strongly recommended but not required

Equivalent Course(s): MENG 36500

MENG 26510. Optics and Photonics. 100 Units.
Electromagnetic radiation in the optical spectrum, or light, plays a fundamentally important role in modern physics and engineering. This introductory course covers the basic properties of light, its propagation in and interactions with matter, and techniques for generating, guiding, and detecting light. Photonic technologies including lasers, optical fibers, integrated optics, optoelectronic devices, and optical modulators will be introduced with selected demonstrations of real-world devices.
Instructor(s): Tian Zhong Terms Offered: Spring
Prerequisite(s): PHYS 13300 or PHYS 14300

MENG 26600. Electronic and Quantum Materials for Technology. 100 Units.
This is an 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.
Instructor(s): Shuolong Yang Terms Offered: Winter
Prerequisite(s): MENG 26100, PHYS 23510, CHEM 26100, or instructor consent
Equivalent Course(s): MENG 36600, CHEM 39300

MENG 26610. Science of Materials. 100 Units.
This is a course covering the principles behind both traditional electronic materials and quantum materials, and connecting the knowledge to various modern applications. It covers basic topics such as Bravais lattice, real and reciprocal space, band theory, classification of materials, physical properties of metals, semiconductors, and insulators. Quantum materials including superconductors, topological materials, and quantum defects will be introduced.
Instructor(s): Shuolong Yang Terms Offered: Autumn
Prerequisite(s): MENG 21300 or equivalent (PHYS 23410 or CHEM 26100), and MATH 18500 or equivalent

MENG 26620. Physics of Solid State Semiconductor Devices. 100 Units.
This course covers the fundamental concepts needed to understand nanoelectronic solid state semiconductor devices. After an overview of the basic properties of semiconductors and electronic transport in semiconductors, we will explore the device physics behind some of the major semiconductor devices that have changed our lives. These include the p-n junction diode, the metal-oxide-semiconductor transistor (MOSFET), the photovoltaics cell (solar cell), the semiconductor light emitting diode (LED) and injection laser, dynamic random access memory (DRAM), and Flash memory. These devices collectively form the backbone behind all computing, communications, and sensing systems used today.
Instructor(s): Supratik Guha Terms Offered: Winter. Offered in alternating academic years. Will be offered in 2026/27 academic year.
Prerequisite(s): MENG 21300 (or PHYS 23500 or CHEM 26100) or PHYS 22700 or PHYS 23600
Equivalent Course(s): MENG 36620

MENG 26630. 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): Andrew Cleland Terms Offered: Spring
Prerequisite(s): PHYS 13300 and CHEM 10200, or equivalent
Equivalent Course(s): MENG 36630

MENG 29700. Undergraduate Research for Molecular Engineering. 100 Units.
PME faculty offer one-quarter research experiences for credit for interested students in the form of this Reading and Research (R & R) course. Students are expected to initiate and develop the research opportunities themselves. A quality grade will be given based on performance in this course. In order to assign a quality grade, an agreement between the sponsoring PME 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 registering for MENG 29700 should complete a "College Reading and Research Course Form" available from the College advisers (https://college.uchicago.edu/advising/registration) and

seek the approval of the Director of Undergraduate Studies for Molecular Engineering (Dr. Mark Stoykovich, stoykovich@uchicago.edu).