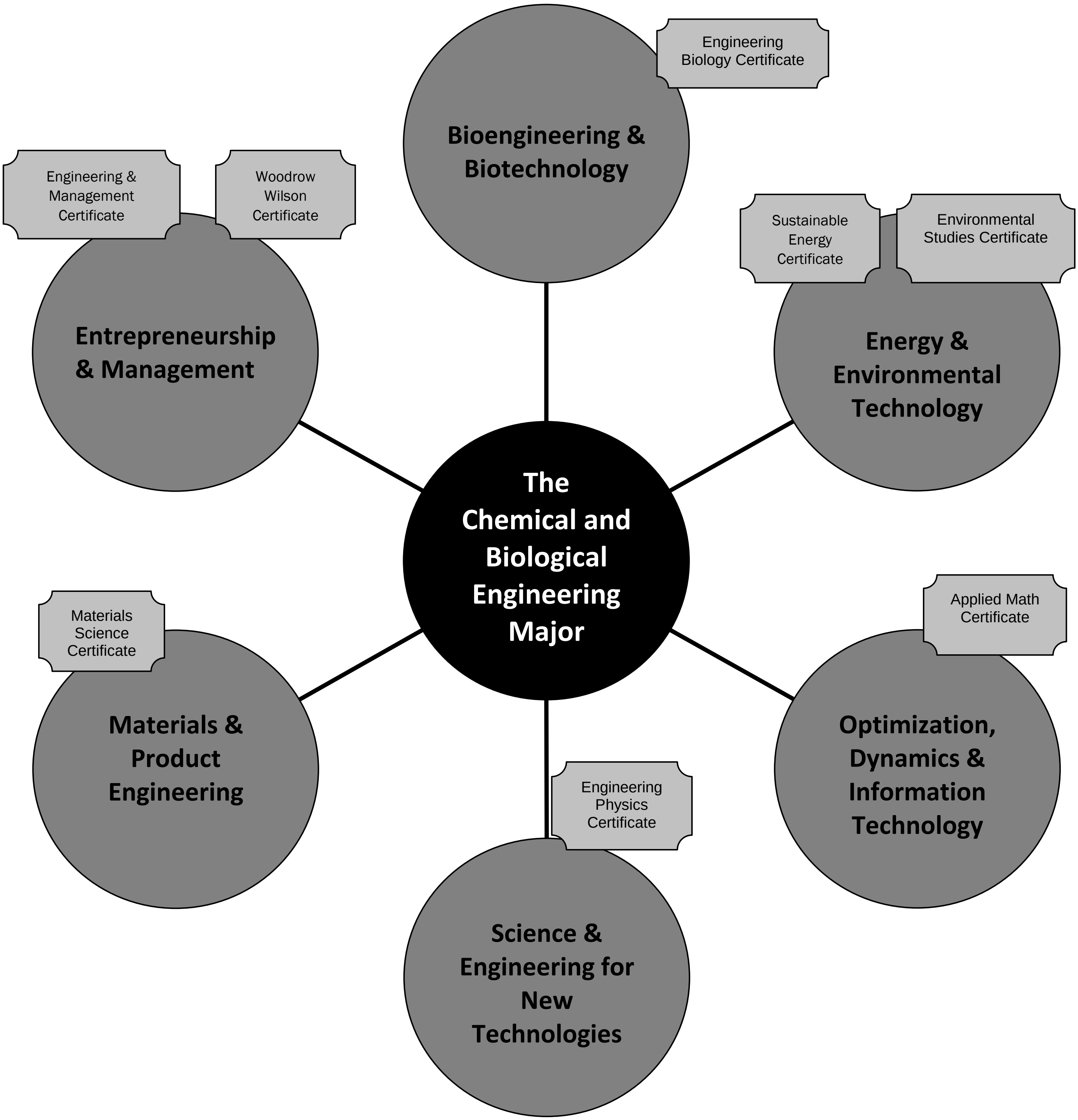
Department of Chemical and Biological Engineering Undergraduate Handbook

Academic Year 2015-16

Revised: March 2016

Chemical and Biological Engineering

PRINCETON


The Chemical and Biological Engineering Major
Bioengineering & Biotechnology
Engineering Biology Certificate
Energy & Environmental Technology
Sustainable Energy Certificate
Environmental Studies Certificate
Optimization, Dynamics & Information Technology
Applied Math Certificate
Science & Engineering for New Technologies
Engineering Physics Certificate
Materials & Product Engineering
Materials Science Certificate
Entrepreneurship & Management
Engineering & Management Certificate
Woodrow Wilson Certificate

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WHAT IS CHEMICAL AND BIOLOGICAL ENGINEERING?

Chemical engineering is pollution control, pharmaceuticals, semiconductors, adhesives, biopolymers, artificial kidneys, oil refineries, solar panels, and ceramics. The American Institute for Chemical Engineers (AIChE) defines a chemical engineer as someone who uses science and mathematics, especially chemistry, biochemistry, applied mathematics and engineering principles, to take laboratory or conceptual ideas and turn them into value added products in a cost effective and safe (including environmental) manner. Chemical engineering is an applied science. While a chemist might discover a new compound in the lab, this compound would be nothing more than a laboratory curiosity unless a chemical engineer used his or her knowledge to quantify, scale up, test and produce the compound as a final product.

So where do Princeton graduates go with their chemical and biological engineering degrees?

Post Graduate plans for the last five graduating classes Class of 2011 – Class of 2015	
Chemical Industry	**14%**
Consulting	**8%**
Electronic Industry, Information Technology	**2%**
Energy & Environment	**3%**
Finance and Banking Industry	**7%**
Food and Personal Products	**2%**
Government Service	**1%**
Graduate School in Engineering	**27%**
Healthcare Industry	**3%**
Medical School	**7%**
Non-Profit Organizations	**1%**
Other Endeavors – pro sports, business school, etc.	**5%**
Petroleum Industry	**3%**
Pharmaceutical Industry	**3%**
Startup Companies	**3%**
Undecided/Unknown	**13%**

THE EDUCATION OF A CHEMICAL AND BIOLOGICAL ENGINEER

To prepare for the kinds of diverse career options mentioned above, one needs a solid foundation in engineering and chemistry, as well as the freedom to take specialized courses in areas of interest. This is provided in the chemical and biological engineering curriculum by having a core of common technical courses and then program electives tailored to the career objectives for each individual student. The program electives explore areas including biotechnology/life sciences, environmental sciences, materials and product engineering, entrepreneurship and management, systems engineering and information technology and engineering science. The senior thesis provides students with the vital experience of integrating their training on an independent research project.

General Notes and Comments on the Four-Year Curriculum

The University requires engineers to successfully complete 36 courses over four years for graduation. (Many students take more than the required 36.) Most students choose to take four 4-course semesters and four 5-course semesters. These 36 courses include:

University, SEAS & Departmental Requirements

School of Engineering and Applied Science (SEAS) Requirements:	
Mathematics	4 Courses
Physics	2 Courses
General Chemistry	1 Course
Computer Proficiency	1 Course
Writing Requirement:	1 Course
Humanities & Social Sciences Electives:	7 Courses (EM req'd. Must satisfy 3 other areas)
Chemical Engineering Core:	9 Courses (including senior thesis)
Advanced Science & Math Requirements:	
Differential Equations	1 Course
Chemistry (300 level)	1 Course
Organic Chemistry	1 Course
Molecular Biology	1 Course
Program Electives*:	
Area of Concentration	3 Courses
Breadth	2 Courses
Free Electives:	2 Courses
Total	36

*At least two of the Program Elective courses must be engineering courses that are on the approved list in the Area of Concentrations with a CBE, CEE, COS, EGR, ELE, MAE, MSE or ORF course number. The advanced chemical engineering course can also be satisfied within the Program Electives.

Of these 36 courses no more than 4 may be taken on a Pass/D/Fail basis unless a course is given <u>only</u> on this basis; in this case the maximum of 4 is increased by one for each such course. Any elective course above the required 36 may be taken Pass/D/Fail. For additional details about the University Pass/D/Fail policy, refer to the Undergraduate Announcement.

Advanced Placement does not reduce the course load required for graduation. Only if a student qualifies for and chooses Advanced Standing is the course load reduced.

School of Engineering and Applied Science Requirements

All engineering students take a common core of courses in mathematics, chemistry, and physics. Advanced placement can satisfy some requirements and allow for more technical or humanities/social science electives.

Mathematics Requirements
  Math 103 and 104 — Calculus
  Math 201 (or 203 or 218) and 202 (or 204 or 217) — Multivariable Calculus and Linear Algebra

Physics Requirements
  Physics 103 (or 105) and 104 (or 106) — General Physics

Computer Proficiency Requirement
  Computer Science 126, 217, or 226

Chemistry Requirements
  Chemistry 201 or 207 — General Chemistry I

Writing Requirement

The ability to write English clearly and precisely is a University requirement that must be satisfied by completing, during the freshman year, a one-semester course that fulfills the writing requirement.

Humanities and Social Sciences (HSS) Electives

The liberal arts component of the students' education is implemented through the Humanities and Social Sciences requirements established by the University. Humanities and Social Science courses taken by CBE students must include at least one course in ethical thought and moral values (EM), which also satisfies the ABET societal impact requirement, and one course in three of the following five areas: epistemology and cognition (EC), foreign language (FL, at the 107/108 level or above), historical analysis (HA), literature and the arts (LA), and social analysis (SA). The remaining three required Humanities and Social Sciences courses, for a total of seven, may be taken in any field in the social sciences and humanities.

Foreign Language courses at the 101, 102, or 103 levels do not count towards the required minimum of seven (7) humanities and social science courses. These courses only count towards the total number of courses taken. Also, any language course taken at the 101 level will not count towards the total number of courses taken unless it is followed by a 102 course.

If you are not sure whether a particular course in the Undergraduate Announcement will satisfy the HSS requirement, ask your academic adviser.

Advanced Requirements

Chemical engineers are distinguished from other engineers by their knowledge of chemistry and life sciences. All chemical engineers are expected to supplement the one semester of chemistry with advanced chemistry and molecular biology. All chemical engineering majors must complete a full year of General Chemistry, at least one semester of Organic Chemistry, and one semester of Molecular Biology. Also, two *separate* approved advanced courses are required, one with advanced chemistry content and one with advanced chemical engineering content.

Chemistry 202 – General Chemistry II
Chemistry 303 — Organic Chemistry
Molecular Biology 214 or 215 – Cellular and Molecular Biology

Advanced Chemistry Content

Students must take one advanced chemistry course from any 300/400/500-level CHM courses (excluding independent work courses, and student elected PDF courses). ABET (formerly Accreditation Board for Engineering and Technology) requires chemical engineering students to display a working knowledge of advanced topics in chemistry. This is satisfied by taking **one advanced chemistry** course. The list below provides some examples of approved courses:

CHM 304 or 304B	Organic Chemistry II
CHM 305/ PHY 305/ ELE 342	Quantum Mechanics/ Quantum Theory/ Quantum Engineering
CHM 306	Physical Chemistry: Thermodynamics and Kinetics
CHM 333	Oil to Ozone: Chemistry of the Environment
CHM 345/ MOL 345	Biochemistry
CHM 371	Experimental Chemistry
CHM 403	Advanced Organic Chemistry
CHM 406	Advanced Physical Chemistry
CHM 407	Inorganic Chemistry I
CHM 408	Inorganic Chemistry II
CHM 470/ GEO 470	Environmental Chemistry of Soils
CHM 525/ ENV 525	Production of Renewable Fuels and Energy
CBE 415	Polymers
CBE 421	Catalytic Chemistry
GEO 363/ CHM 331/ ENV 331	Introduction to Environmental Geochemistry
GEO 418	Environmental Aqueous Geochemistry

Advanced Math Requirement

Many processes in chemical engineering are described by differential equations. All students in Chemical and Biological Engineering must complete a course in differential equations (MAE 305 or MAT 427 or APC 350) by the end of the fall term of the junior year.

Advanced Chemical Engineering Content

Students must take one advanced chemical engineering course from any 300/400/500-level CBE courses (excluding independent work courses, and student elected PDF courses).

Chemical and Biological Engineering Core Courses

To qualify for a Chemical and Biological Engineering degree, students must take a core of 9 departmental courses. This is required by ABET and Princeton University. The following nine courses are required:

CBE 245	Introduction to Chemical Engineering Principles
CBE 246	Thermodynamics
CBE 250	Separations in Chemical Engineering and Biotechnology
CBE 341	Mass, Momentum and Energy Transport
CBE 346	Chemical Engineering Laboratory
CBE 441	Chemical Reaction Engineering
CBE 442	Design, Synthesis, and Optimization of Chemical Processes
CBE 454	Senior Thesis (counts as two)

Students may petition to substitute a 1-semester independent work project plus an approved technical elective for the 2-semester senior thesis. To be eligible for departmental honors one must complete a 2-semester senior thesis.

Chemical and Biological Engineering Program Electives

Program Electives are used to satisfy requirements for areas of concentration and breadth. These are discussed in detail in the following pages.

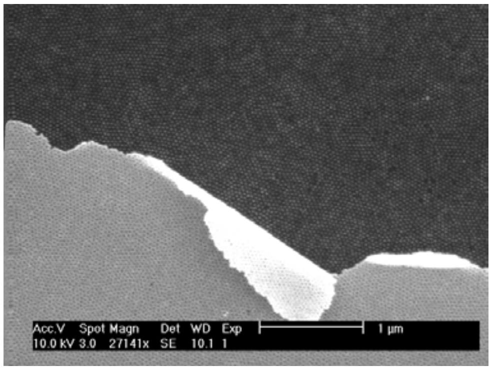
ABET Accreditation

The Chemical Engineering Program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

ABET requires chemical engineering students to complete a minimum of 12 engineering topic courses. This is satisfied by completing the nine CBE core courses (including the double credit thesis), plus the following: the required advanced chemical engineering course, and at least two program electives chosen from CBE, CEE, COS, EGR*, ELE, MAE, MSE, or ORF that are on the approved list of courses in the areas of concentration. **EGR courses that are non-credit do not count for this requirement.*

Integrated Science Curriculum

The integrated science program is intended for students who are considering concentrating in the sciences or engineering. It provides an alternative path into the Departments of Chemistry, Computer Science, Molecular Biology, and Physics. ISC/CHM/COS/MOL/PHY 231, 232, 233, 234 can be taken in the freshman year; ISC 231 and ISC 232 in the fall term and ISC 233 and ISC 234 in the spring term. These courses can be substituted for CHM 201-202, PHY 103-104 or 105-106, MOL 214-215, and COS 126 in the freshman year. ISC/CHM/COS/MOL/PHY 235, 236 can be taken in the sophomore year. Students who take ISC 231-234 cannot also take MOL 214/215 for credit. These students can satisfy the CBE “Molecular Biology” requirement by taking another course offered by, or cross listed with, Molecular Biology at the 300-level and above. For more information, consult the *Undergraduate Announcement* or www.princeton.edu/integratedscience.



An example of nanofabrication through the replication of a block copolymer thin film template. Top portion of the image shows an array of gold dots, 30 nm diameter and 18 nm thick, on a silicon wafer substrate. The lower portion shows the mask through which these dots were deposited: a 10 nm-thick silicon nitride membrane, perforated with holes of 30 nm diameter.

[Image courtesy of Young-Rae Hong and Professor Richard A. Register]

Program Electives

The program electives provide students with an introduction to the breadth of advanced areas of chemical and biological engineering and to have the students pursue one area in greater depth. Six areas have been identified as areas of concentration and are listed in Table II along with courses that satisfy the requirements. Depth in an area of concentration is accomplished by taking three courses from a prescribed list and carrying out senior independent work (senior thesis) in the same area of concentration. Students are required to take courses in two different areas outside their concentration to provide breadth. *Except under exceptional circumstances, technical electives cannot be taken anywhere but at Princeton University.* A number of courses in three of the areas of concentration can also satisfy the advanced chemistry content and advanced chemical engineering course requirements. By judicious choice of program electives students can free up two electives within the 36-course requirement.

Program electives may be used to partially or completely fulfill course requirements for the University certificate programs. Certificate programs readily accessible to Chemical and Biological Engineers include Engineering Biology, Engineering Physics, Environmental Studies, Materials Science and Engineering, Applied and Computational Mathematics, Sustainable Energy, Applications of Computing, Finance and Engineering Management Systems. For further information on certificate programs the student should consult the appropriate certificate program handbooks or websites.

Areas of Concentration for Chemical and Biological Engineering Majors

- **Bioengineering and Biotechnology**
- **Entrepreneurship and Management**
- **Energy and Environmental Technology**
- **Materials and Product Engineering**
- **Optimization, Dynamics and Information Technology**
- **Science and Engineering for New Technologies**

Courses in Areas of Concentration

Course	Course Description	Additional Requirements
Bioengineering and Biotechnology, Track 1		
CBE 423	Biologically Inspired Materials	Not open to Freshmen
CBE 432	Dynamics of Cellular Processes	CBE 441, MAT 303 or MAE 305, MOL 214
CBE 433	Introduction to the Mechanics and Dynamics of Soft Living Matter	
CBE 438/MOL 438	Biomolecular Engineering	
CBE 439	Quantitative Physiology and Tissue Design	
CBE 440	The Physical Basis of Human Disease	
CBE 443	Separations in Chemical and Biochemical Processes	CHM 202 and MAT 101/3 and MAT 102
CBE 447	Metabolic Engineering	
CBE 573/ELE 573	Cellular and Biochemical Computing Systems	
CHM 412	Applied Quantitative Analysis: Molecular Recognition	CHM 201/207 and 202; or CHM 215 or equivalent
CHM 440	Drug Discovery in the Genomics Era	2 terms of organic chemistry
CHM 515	Biophysical Chemistry I	Permission of instructor
CHM 538	Topics in Biological Chemistry – Chemical Tools to Study Biological Systems	
CHM 542	Principles of Macromolecular Structure: Protein Folding, Structure and Design	
CHM 543	Adv Topics in Structural Biology- Neuro-developmental Disorders from a Molecular Point of View	Juniors, seniors, grad students only.
CHM 544/ENV 544	Metals in Biology	CHM 301/2 or CHM 303/4
EEB 320/MOL 330	Molecular Evolutionary Genetics	MOL 214, MOL 215, or any upper level MOL course
EEB 325	Mathematical Modeling in Biology & Medicine	Enrollment by application
EEB 327/MOL 327	Immune Systems: From Molecules to Populations	EEB 211 and MOL 214
ENE 418/CBE 418	Fundamentals of Biofuels	CHM 301/303, MOL 345 or MOL 214/215
GEO 428	Biological Oceanography	College level Bio, CHM, PHY
MAE 344	Introduction to Bioengineering and Medical Devices	MAT 103/4, PHY103/4

MOL 340	Molecular and Cellular Immunology	MOL 214
MOL 342	Genetics	MOL 214 or 215
MOL 345/CHM 345	Biochemistry	MOL 214/215 and CHM 304/304B
MOL 348	Cell and Developmental Biology	MOL 342 or MOL 345
MOL 408	Cellular and Systems Neuroscience	MOL 214, PHY 103/4, MAT 103/4, PSY 258
MOL 410	Introduction to Biological Dynamics	MAT 103 or equivalent
MOL 433	Biotechnology	MOL 342 or MOL 345
MOL 434	Macromolecular Structure and Mechanisms in Disease	MOL 345 or permission from instructor
MOL 435	Pathogenesis and Bacterial Diversity	MOL 342 or permission from instructor
MOL 437	Computational Neurobiology	PHY 103/4, MAT 201/2
MOL 448/CHM 448	Chemistry, Structure, and Structure Functions of Nucleic Acids	
MOL 455/COS 455	Introduction to Genomics and Computational Molecular Biology	
MOL 457	Computational Aspect of Molecular Biology	One 300-level MOL, CHM course
MOL 459	Viruses: Strategy and Tactics	MOL 342 or MOL 348 or permission of instructor
MOL 523	Molecular Basis of Cancer	
NEU 258/PSY 258	*Fundamentals of Neuroscience**	
NEU 259B/PSY 259B	*Introduction to Cognitive Neuroscience**	NEU 258/PSY 258
NEU 408/MOL 408/ PSY 404	Cellular and Systems Neuroscience	MOL 214 or 215, PSY 258, MAT 103, PHY 104
NEU 437/MOL 437/ PSY 437	Computational Neuroscience	MOL 410 or basic linear algebra, probability, MAE 305
PSY 406	Functional Neuroanatomy	
PSY 407	Developmental Neuroscience	PSY 208, 256 or 258
QCB 511/CBE 511	Modeling Tools for Cell and Developmental Biology	
**PSY 258 and 259B if satisfying the certificate in neuroscience.*		

Entrepreneurship and Management, Track 2		
CBE 260/EGR 260	Ethics and Technology: Engineering in the Real World	
CEE 334/ WWS 452/ ENV 334/ ENE 334	Global Environmental Issues	AP chemistry, CHM 201, or permission of instructor
CEE 460	Risk Assessment and Management	ORF 245, MAT 202
CHV 331/ WWS 372	Ethics and Public Health	
COS 432	Information Security	COS 217, 226
ECO 310	Microeconomic Theory: A Mathematical Approach	ECO 100 & MAT 200 or 201

ECO 311	Macroeconomics: A Mathematical Approach	ECO 100 & ECO 101 & MAT 200 or MAT 201
EGR 437/ MAE 437/ ELE 437	Innovation Process Leadership	
EGR 492	Radical Innovation in Global Markets	
EGR 494	Leadership Development for Business	
EGR 495	Special Topics in Entrepreneurship	
EGR 497	Entrepreneurial Leadership	
ELE 491	High-Tech Entrepreneurship	
ENV 324/EGR 324	Environmental Entrepreneurship	
GEO 366/ENV 339 /WWS 451/ ENE 366	Climate Change: Impacts, Adaptation, Policy	MAT 101/2, CHM 201/2 or PHY 101/2, GEO 202
ORF 245	Fundamentals of Engineering Statistics	
ORF 335	Introduction to Financial Engineering	ECO 102, MAT 104, ORF 309
ORF 435	Financial Risk Management	ORF 245, ECO 202, 335, or 465
WWS 373/ CHV 373	Welfare, Economics and Climate Change Mitigation Policy	Not open to freshmen
**ECO 362 if satisfying the certificate in finance.*		

Energy and Environmental Technology, Track 3		
AST 309/MAE 309/ PHY 309	Science and Technology of Nuclear Energy: Fission and Fusion	PHY 101-102, 103-104, 107-109, MAT 201 or 203, EGR 191-194
CBE 335/ MAE 338/ ENV 335	The Energy Water Nexus	Juniors and seniors only.
CEE 301	Introduction to Environmental Engineering	CHM 201 or MSE 104
CEE 304/ ENV 300/ ENE 304	Environmental Implications of Energy Technologies	CHM 201 and MAT 104
CEE 306	Hydrology	MAT 201 (concurrent)
CEE 308	Environmental Engineering Laboratory	CEE 303/301
CEE 311/CHM 311/ GEO 311	Global Air Pollution	CEE 303/301 or CHM 303/304
CEE 334/ WWS 452/ ENV 334/ ENE 334	Global Environmental Issues	AP chemistry, CHM 201, or permission of instructor
CEE 471	Introduction to Water Pollution Technology	
CEE 474/ENV 474	Special Topics in CEE- Design and Construction of Environmental Sensors	
CEE 477/ ENE 477	Engineering Design for Sustainable Development	CEE 303/301 or equivalent
CHM 333	Oil to Ozone: Chemistry of the Environment	Any 200 level CHM course
CHM 525/ENV 525	Production of Renewable Fuels and Energy	
ECO 429	Issues in Environmental and Natural Resource Economics	
ELE 431	Solar Energy Conversion	Completed freshman science or EGR courses. Jr & Sr only

ENE 418/CBE 418	Fundamentals of Biofuels	CHM 301/303, MOL 345 or MOL 214/215
ENE 558/ CBE 558/ CEE 585	U.S. Shale Gas and Tight Oil: Implications and Opportunities	
ENV 201A, 201B	Fundamentals of Environmental Studies: Population, Land Use, Biodiversity, Energy	
ENV 202A, 202B	Fundamentals of Environmental Studies: Climate, Air Pollution, Toxics and Water	
ENV 204	Global Warming: Causes, Consequences, Policy Responses	
ENV 324/EGR 324	Environmental Entrepreneurship	
ENV 531/GEO 531/ CEE 583	Topics in Energy and the Environment: Introduction to Petroleum Engineering	
GEO 220A or 220B	Weather and Climate	
GEO 322	Biogeochemical Cycles and Global Change	CHM 201/2, MAT 101/2
GEO 363/CHM 331/ ENV 331	Environmental Geochemistry: Chemistry of the Natural Systems	CHM 201 or AP chemistry
GEO 364/CHM 364	Earth Chemistry: Major Realms of the Planet	CHM 201, MAT 103
GEO 366/ENV 339/ WWS 451/ ENE 366	Climate Change: Impacts, Adaptation, Policy	MAT 101/2, and CHM 201/2 or PHY 101/2, GEO 202
GEO 418	Environmental Aqueous Geochemistry	One year of CHM, CHM 306 recommended
GEO 423/ CEE 423	Dynamic Meteorology	(1) 200-level math course
GEO 424/ CEE 424 / ENE 425	Introductory Seismology	PHY 104 and MAE 305
GEO 470/ CHM 470	Environmental Chemistry of Soils	GEO 331 or any CHM course
MAE 328/ EGR 328/ ENV 328	Energy for a Greenhouse-Constrained World	MAE 221, MAE 222
MAE 424/ ENE 424	Energy Storage Systems	MAE 221 or equiv., Freshmen PHY & CHM
MAE 427	Energy Conversion and the Environment: Transportation Applications	MAE 221, MAE 222
WWS 306/ECO 329 /ENV 319	Environmental Economics	MAT 103 and ECO 300 or equivalent

Materials and Product Engineering, Track 4		
CBE 415 /CHM 415	Polymers	CHM 301/303
CBE 422	Molecular Modeling Methods	COS 126 and MAE 305
CBE 423	Biologically Inspired Materials	Not open to Freshmen
CBE 425	Polymer Rheology	Juniors and Seniors Only
CBE 433	Introduction to the Mechanics and Dynamics of Soft Living Matter	
CBE 526/ CHM 527/ MSE 526	Surface Science: Processes and Probes	Not open to Freshmen
CEE 364	Materials in Civil Engineering	
CHM 403	Advanced Organic Chemistry	CHM 301/302 or 304 or 303

CHM 409	Structural Solid State Chemistry	Gen Chem. or AP and thermo
ELE 341	Solid State Devices	ELE 208
ELE 342	Principles of Quantum Engineering	PHY 103 and 104
ELE 455/ CEE 455/ MAE 455/ MSE 455	Mid-Infrared Technologies for Health and the Environment	
ELE 441	Solid-State Physics I	ELE 342 or PHY 208 and 305 or equiv.
ELE 442	Solid-State Physics II	ELE 441 or PHY 405
ELE 449	Materials and Solid-State Device Laboratory	ELE 208, 342
GEO 378	Mineralogy	
MAE 324	Structure and Properties of Materials	MAE 221, CEE 205
MAE 334	Materials Selection and Design	CEE 205
MSE 301	Materials Science and Engineering	
MSE 302	Laboratory Techniques in Materials Science and Engineering	MSE 301
MSE 531/ELE 531	Introduction to Nano/Microfabrication	

Optimization, Dynamics, and Information Technology, Track 5		
CBE 422	Molecular Modeling Methods	COS 126 and MAE 305
CBE 445	Process Control	MAE 305
CBE 448	Introduction to Nonlinear Dynamics	MAE 305 or MAT 203/303
CBE 520	Molecular Simulation Methods	Not open to Freshmen
CBE 527	Nonlinear and Mixed-Integer Optimization	Not open to Freshmen
COS 217	Introduction to Programming Systems	COS 126
COS 226	Algorithms and Data Structures	COS 126
COS 323	Computing for the Physical and Social Sciences	COS 126 and MAT 104
COS 333	Advanced Programming Techniques	COS 217 and COS 226
COS 402	Artificial Intelligence	COS 226
COS 424	Interacting with Data	MAT 202 and COS 126
ECO 317	*Economics of Uncertainty**	
EEB 355/ MOL 355	Introduction to Statistics for Biology	
ORF 245	Fundamentals of Engineering Statistics	
ORF 307	Optimization	MAT 202
ORF 309	Probability and Stochastic Systems	MAT 201, 203, 217
ORF 311	Optimization under Uncertainty	ORF 307 or MAT 305/309
ORF 406	Statistical Design of Experiments	ORF 245
ORF 409	Intro to Monte Carlo Simulation	ORF 245, 309
ORF 411	Operations and Information Engineering	ORF 307, 309, 245
ORF 417	Dynamic Programming	ORF 307 and ORF 309
**ECO 317 if satisfying the certificate in finance.*		

Science and Engineering for New Technologies, Track 6		
Transport Phenomena		
CBE 342/CBE 501	Fluid Mechanics	CBE 341
CBE 425	Polymer Rheology	Open to Juniors and Seniors Only
MAE 306/MAT 302	Mathematics in Engineering II	MAE 221, 222
MAE 336	Viscous Flows	MAE 221, 222
MAE 423	Heat Transfer	
Chemical Technology		
CBE 421/CHM 421	Catalytic Chemistry	CHM 301
CHM 302/304	Organic Chemistry II	CHM 301
CHM 305	The Quantum World	CHM 202 or 215, MAT 102 or 104, PHY 101
CHM 306	Physical Chemistry: Chemical Thermodynamics and Kinetics	CHM 201/202 (or 207), 204/215, MAT 104, PHY 101/102/103/104
CHM 403	Advanced Organic Chemistry	301 and 302 (or 304); or, 303 and 304
CHM 405	Advanced Physical Chemistry: Quantum Mechanics	CHM 202 or 215, MAT 201, 202, PHY 103
CHM 406	Advanced Physical Chemistry: Chemical Dynamics and Thermodynamics	CHM 202, 215 or CBE 342, MAT 201
CHM 407	Inorganic Chemistry: Structure and Bonding	CHM 201/202, 207/208, 215
CHM 408	Inorganic Chemistry: Reactions and Mechanisms	Juniors and Seniors only
Engineering Physics		
PHY 203/205	Classical Mechanics	PHY 103/4, 105/6, MAT 201 or 203
PHY 208	Principles of Quantum Mechanics	PHY 203 or 205, MAT 203 or 217 and 204 or 218
PHY 301	Thermal Physics	PHY 106, 203, 205 or 208
PHY 304	Advanced Electromagnetism	PHY 104 or PHY 106
PHY 305	Introduction to Quantum Theory	PHY 208
Electronic Materials Processing		
ELE 206/COS 306	Introduction to Logic Design	
ELE 208	Integrated Circuits: Practice and Principles	CHM 201, PHY 102/4
ELE 341	Solid State Devices	ELE 208
ELE 342	Principles of Quantum Engineering	PHY 103 and 104
ELE 441	Solid State Physics I	ELE 342 or PHY 208 and PHY 305
ELE 442	Solid State Physics II	ELE 441 or PHY 405

The advanced chemistry course requirement and the advanced chemical engineering course requirement can both be satisfied by electives in the areas of concentration.

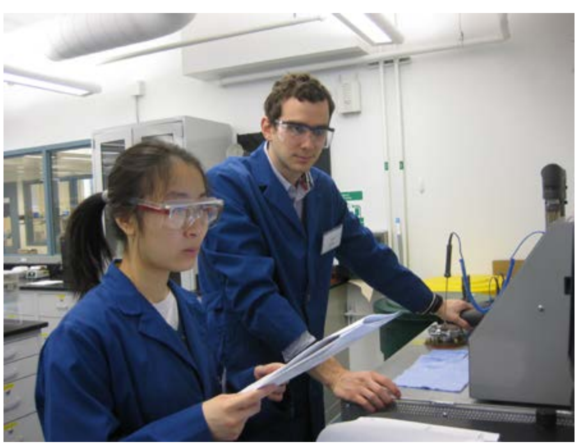
The Four-Year Curriculum

A "bottom-line" four-year curriculum is shown below. In the following outline, the curriculum assumes no Advanced Placement. In this outline, we have also assumed that students will take two 200-level chemistry courses and will do one year of senior thesis (CBE 454) to complete the 9 departmental courses.

Many students enter their undergraduate studies with one or more terms of Advanced Placement in Chemistry and/or Mathematics. Such AP credit may change the curriculum significantly. Hence, the Freshman Advisers and the Departmental Representative will work with students to design personalized curriculums.

A FOUR-YEAR CHEMICAL AND BIOLOGICAL ENGINEERING CURRICULUM

	FALL	SPRING
FRESHMAN YEAR	MAT 103 Calculus	MAT 104 Calculus
	PHY 103 Physics	PHY 104 Physics
	CHM 201 Chemistry	CHM 202 Chemistry
	HSS Humanities/Social Science	Computer Requirement
		Writing Requirement
SOPHOMORE YEAR	MAT 201 Multivariable Calculus	CBE 246 Thermodynamics
	CBE 245 An Introduction to Chemical Engineering Principles	MOL 214 Biology
	CHM 303 Organic Chemistry	MAE 305 Differential Equations
	MAT 202 Linear Algebra	Program Elective
	HSS Humanities/Social Science	HSS Humanities/Social Science
JUNIOR YEAR	CBE 250 Separations Process	CBE 346 Laboratory
	CBE 341 Transport	CBE 441 Reactors
	Program Elective	Program Elective
	Program Elective	HSS Humanities/Social Science
	HSS Humanities/Social Science	
SENIOR YEAR	CBE 442 Design	CBE 454 Senior Thesis
	CBE 454 (does not appear on transcript)	HSS Humanities/Social Science
	Program Elective	Open Elective
	HSS Humanities/Social Science	Open Elective



Freshman Year

Advanced Placement in chemistry or mathematics allows students to take courses in these areas normally assigned to later years in the curriculum.

Although the writing requirement must be fulfilled within the first two years, it is strongly recommended that it be fulfilled in the freshman year. Even a 5 on the AP English exam will not exempt students from the writing requirement.

A student desiring a head start in Chemical and Biological Engineering and having Advanced Placement in chemistry may elect to take CBE 245 Introduction to Chemical Engineering, in the fall term. This will permit them to take CBE 246 Thermodynamics, or MOL 214 Molecular Biology, in the spring term, thus freeing up upperclass years for more technical or humanities electives.

Computer Science proficiency is required by the School of Engineering and Applied Science (SEAS) and may be demonstrated by completion of COS 126 General Computer Science. Most students satisfy this requirement in the first year. It is the policy of SEAS that this requirement must be satisfied by the students by taking an appropriate course at Princeton University.

Any student who has completed the above freshman year or its equivalent has the proper preparation for entrance into the Department of Chemical and Biological Engineering. The choice of department is normally made toward the end of freshman year.

Sophomore Year

Required courses such as Differential Equations (MAE 305), Molecular Biology (MOL 214/215), and Organic Chemistry (CHM 303) should be completed by the end of sophomore year.

Students who took CBE 245 and CBE 246 in their freshman year may elect to take CBE 250 Separations Processes and elective courses in their sophomore year.

Students who are not yet fully committed to a department, but are still considering Chemical and Biological Engineering at the beginning of their sophomore year, should elect CBE 245 along with basic courses in the alternate department considered. This will permit such students to delay their final choice of department until the spring of the sophomore year.

Should an A.B. student wish to transfer to Chemical and Biological Engineering at the beginning of the sophomore year, he/she must have the necessary mathematics and chemistry background. However, if that student has had no physics, it may be taken in the sophomore year.

After the fall term of sophomore year, transfer into the Department is difficult without the background outlined in the two years above but not impossible. Outstanding students who are well motivated have been accommodated in the past and they have gone on to do very well. Please see the Departmental Representative for details.

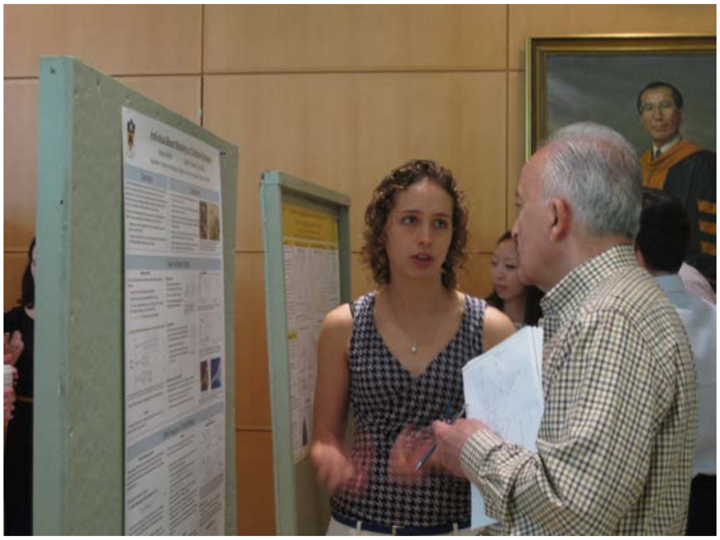
Junior Year

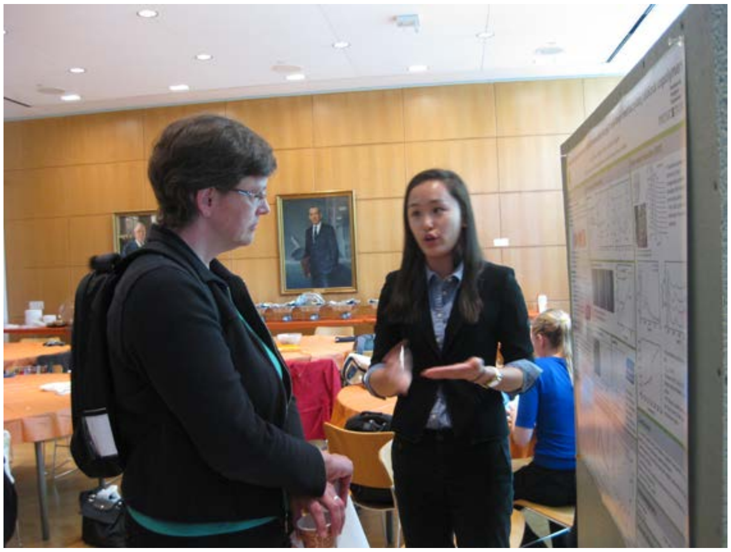
Students are advised to attempt to complete as many of their program electives during their junior year as possible.

Senior Year

It is the Department's desire to be as flexible as possible. Students are expected to take a two-semester senior thesis project, which is the norm. The minimum requirement is a one semester thesis plus one additional approved chemical and biological engineering elective course. Students who perform one semester of independent work are ineligible for departmental honors. Please consult the Departmental Representative in April of the junior year if you plan on a one-semester independent project. In some cases, arrangements have been made to have the senior thesis research conducted in other departments.

Although CBE 454 appears on the transcript only in the spring term, it is viewed as being equivalent to one course in the fall and one course in the spring. SEAS requires each student to take at least four courses each semester. Thus every student doing a two-term thesis must sign up for the CBE 454 and three other (taught) courses in the spring semester. The student is permitted to sign up for only three courses in the fall semester (with CBE 454 not appearing on the course card being the fourth course).

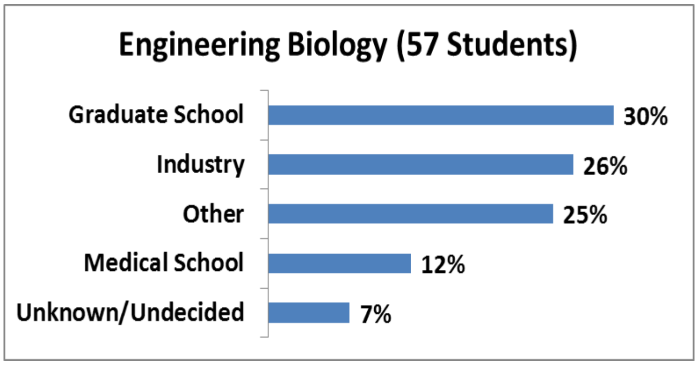


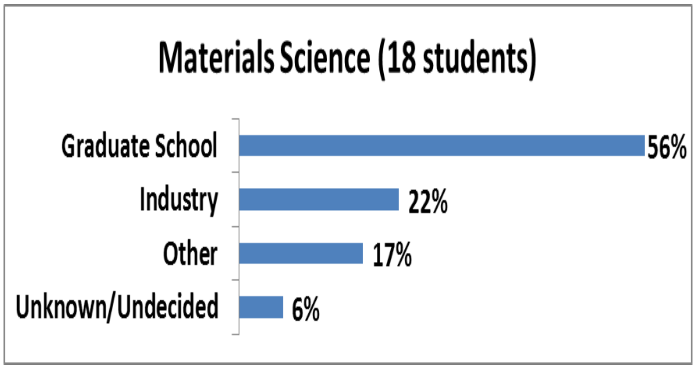


CERTIFICATE PROGRAMS

Certificate programs may be pursued in parallel with one of the departmental concentrations through appropriate course selections. Certificates are recognition of proficiency in a sub discipline. The CBE curriculum is organized to permit the program electives to satisfy some of the certificate requirements as well. The charts below show the certificates awarded to CBE students and the career choices of the certificate recipients.

Future plans for Certificate Holders 2013-2015





Many departments at the University offer certificate programs. East Asian Studies, Musical Performance, Creative Writing, Theater and Dance, Language and Culture, and Finance are just a sample of the certificate programs our current undergraduates are pursuing. Some of the popular certificate programs for Chemical and Biological Engineering students are listed below.

Program	Program Adviser, Contact Info
Engineering Biology	Celeste M. Nelson, celesten@princeton.edu
Engineering Physics	Stephen A. Lyon, lyon@princeton.edu
Engineering and Management Systems	Warren B. Powell, powell@princeton.edu
Environmental Studies	Lars O. Hedin, lhedin@princeton.edu
Finance	Markus K. Brunnermeier, markus@princeton.edu
Materials Science and Engineering	Craig Arnold, cbarnold@princeton.edu
Sustainable Energy	Yiguang Ju, yju@princeton.edu

INDEPENDENT WORK

General

The Department strongly believes that every graduate should be able to pursue effectively the study of some subject by themselves. It also believes that such study should come late enough in a student's academic career so that the experience is not only that of learning something new but of organizing that which is already known and seeing the two in perspective. The department encourages sophomores and even freshman to seek out opportunities to participate in research activities sponsored by the faculty. These are viewed as excellent preparation for junior and senior independent work.

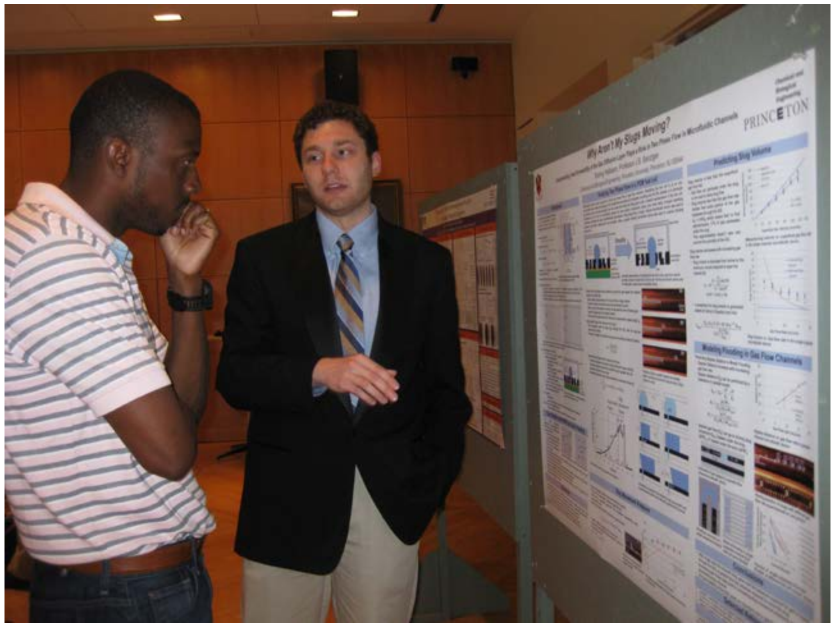
In spite of the above conviction, the Department recognizes that occasionally a student may benefit more from additional course work rather than from independent study. Consequently, although it officially requires at least one term of senior independent study, it is prepared to make a limited number of exceptions to this rule where students can make good cases for them. Note that one-term projects are either CBE 451 (fall term) or CBE 452 (spring term), and two-term projects are CBE 454 Senior Thesis.

Junior Independent Work

Typically, several students engage in Junior Independent Work. Students wishing to conduct Junior Independent work should identify a faculty mentor and a topic. The requirements for satisfactory completion of the study include a written report, and may include an oral presentation to peers and the faculty. Students register for CBE 351 in the fall and CBE 352 in the spring term. Students are required to complete a lab safety course before starting laboratory research. Note that CBE 351 and CBE 352 are considered free electives and do not count towards any requirements.

Senior Thesis Work

Most seniors consider their senior thesis experience--working with a single faculty member on a challenging problem--to be one of the high points of their education. Each spring the department circulates to the junior class an extensive document that summarizes suggested topics, indicating whether they are experimental or computational projects. Students are allowed time to consider these selections, talk with faculty or make suggestions of their own. At the end of this period, they submit a rank list of topics, each under a different faculty member. The faculty then tries to satisfy student interest and yet maintain a reasonable distribution of students throughout the department. Even with large classes it usually is possible to grant each student one of his/her first two choices. No student is ever required to work on a project in which he/she has no interest.

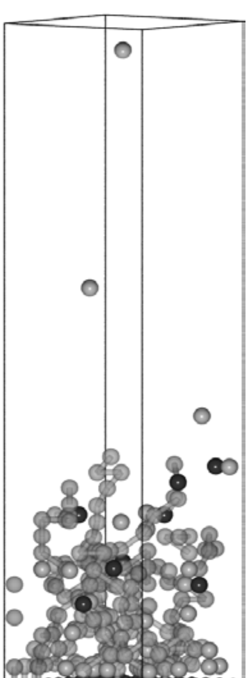


Thomas Hellstern '12 and Professor Rodney D. Priestley
Senior Thesis Poster Presentation in the Friend Center for Engineering

The requirements for two-term projects are two progress reports (one submitted after Thanksgiving and one early in the spring term), a final thesis, a poster presentation, and a final oral examination during the Reading Period in the spring semester. In order to assure more uniform evaluation of students, two faculty members grade students on the thesis, poster presentation, and the final examination. The Senior Thesis Guide issued by the Department has additional details.

For one-term projects, one progress report submitted before the midterm break, a final written report and a final oral examination are required. The written report is due in the first week of the reading period and the oral examination will be held during the second week of reading period.

For one-term projects students register for CBE 451 for the fall term and CBE 452 in the spring. If a two-term project is chosen the student registers for CBE 454 in the spring term only. Nothing appears on the transcript for the fall term. CBE 454 automatically carries double credit; that fact is noted on the official transcript.



An illustration of the charge on the surface of polymer chains.

[Image courtesy of Owen Hehmeyer and Professor A.Z. Panagiotopoulos]

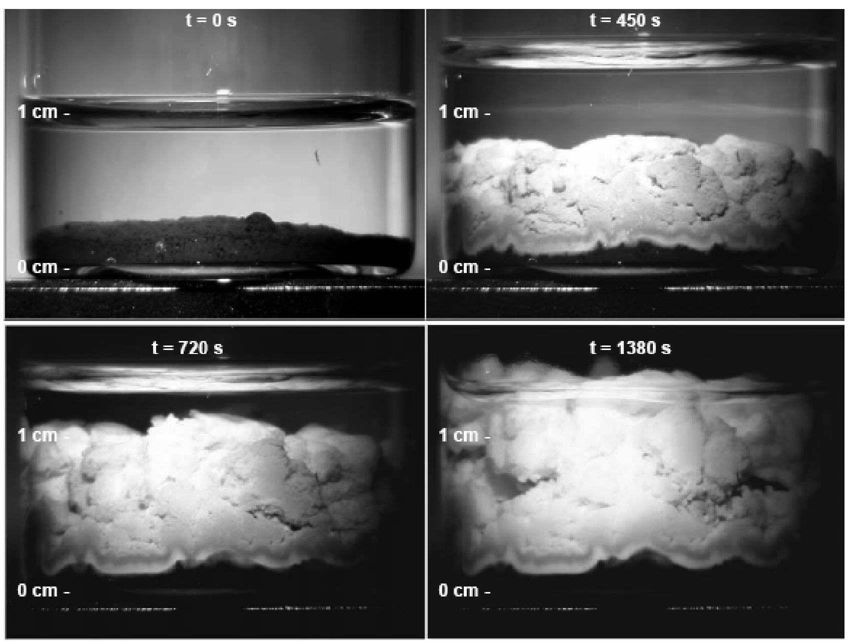
Senior Thesis / Independent Work Funding

Seniors in the School of Engineering and Applied Science may apply for support for senior thesis and independent work research from funds administered by the SEAS Dean's Office. These funds are normally restricted to consumable supplies, software, small equipment and parts, and travel for field experiments. They do not cover conference travel, books and journals, copying and thesis preparation costs, or capital equipment. Funding per project varies, but will normally not exceed $600; requests above that amount will be considered only if accompanied by a special request letter from your adviser. All awards are contingent on the availability of funds.

The SEAS Undergraduate Affairs Office will send out information, via email, to students explaining how and when to apply for funding for senior thesis or independent work projects.

Application materials must be submitted, according to the deadline depending on the semester to Dean Peter Bogucki.

For additional information please consult the School of Engineering and Applied Science website at: http://engineering.princeton.edu/undergraduate/



Sulfur removal from petroleum by reaction with PbO.

[Image courtesy of Professor Jay B. Benziger]

Sample Senior Thesis Titles

Aksay	*Metal-Substituted Alumoxanes as Colloidal Nanocatalysts for Enhanced Fuel Combustion*
	L^3-templated Nanostructured Silica
Avalos	*Yeast engineering for the production of advanced biofuels from cellulosic and hemicellulosic sugars*
	Mitochondrial engineering for the production of fuels, plastics and commodity chemicals
Benziger	*Gas-Liquid Flows in Complex Microfluidic Channel Structures*
	Characterization of Mechanical Transport Properties of Ionomer and Ionomer/Metal Oxide Composite
Brangwynne	*Monitoring and modeling the transport dynamics of nucleolar proteins and RNA using a novel microfabrication-based assay*
	Measuring and manipulating RNA/protein bodies using microinjected nanoparticles
Brynildsen	*Investigating the carbon source dependency of nitric oxide (NO) metabolism*
	Investigating H_2O_2 metabolism in the absence of the major detoxification systems
Kevrekidis	*Dynamics of Coupled Heterogeneous Neurons in Complex Network Structures*
Koel	*Photochemistry at modified hematite (α-Fe2O3) surfaces for production of renewable hydrogen*
Link	*Studies on Homodimerization of Bcl-2 Family Protein*
	Maturation Mechanism of Microcin J25
Loo	*Design and Cost Analysis of Low-Carbon Transportation Fuel and Electricity Coproduction that Includes Carbon Capture and Storage in Shale Gas Formations*
Nelson	*Pattern Formation in Avian Lung Development*
	Hypoxia and the mechanical microenvironment
Panagiotopoulos	*Monte Carlo Simulation of Multiblock Copolymers in Solution*
Priestley	*Glass Transition Temperature, Physical Aging, and Fragility Polymer Nanospheres*
	Non-Contact Method to Measure the Viscoelastic Properties of Ultrathin Films
Prud'homme	*Nanoparticle Drug Delivery for Cancer and Drug Resistant TB*
	Formation of lpid-based magnetic microparticles for in vitro drug release assays
Register	*In-Plane and Out-of-Plane Microdomain Orientation in Thin Films of Polystyrene-Poly(2-ethylhexylmethacrylate) Diblock Copolymers*
	The Crystal-Crystal Transition in Hydrogenated Polynorbornene
Shvartsman	*Epithelial morphogenesis and dorsal appendage formation in Drosophila*
	Input/Output Analysis of the dpERK Gradient in Drosophilia Embryogenesis
Sundaresan	*Filtered two-fluid models for reacting gas-particle flows from two-dimensional simulations of an isothermal riser reactor*
	Methanol Sorption and Permeation Properties of PEM Fuel Cell Membranes

GRADUATION REQUIREMENTS

School of Engineering and Applied Science

The 36-course requirement cited above may be met by four 4-course terms and four 5-course terms. However, a student may not reduce any term below four courses by taking additional 5-course terms. The minimum number of courses a student may take in any one term is four. Independent Work counts as one course in each term it is taken. Note: Although the senior thesis (CBE 454) appears only in the spring term course card, it counts as one course in the fall and one in the spring. Seniors must be registered for at least three "taught" courses each semester. The three taught courses plus the senior thesis satisfy the four course requirement.

The School also specifies that no required course may be taken on a Pass/D/Fail basis. For the CBE department, this regulation means that all the core requirements and chemical and biological engineering requirements must be taken on a graded basis.

The School also requires that the departmental average must be at least 2.000 to permit a student to graduate.

ACADEMIC HONORS

The Department awards academic honors (Honors, High Honors, Highest Honors) using departmental grade point average (GPA) as one of the criteria. To compute departmental GPA, the grades from CBE 245, 246, 250, 341, 346, 441, 442 and 454 are taken into consideration along with grades from the five program elective courses. If the student has taken more than five program electives, the five courses with the highest grades that satisfy the concentration and breadth requirements are taken in the departmental GPA calculation. The average GPA based on these 14 courses will be the Departmental GPA. The Departmental GPA is used by the faculty in the determination of awards and honors.

There are no automatic ranges in GPA for awarding honors. The Departmental GPA is only one of several factors that go into the decision process for deciding honors. A two-semester senior thesis is required for departmental honors. Quality of the senior thesis (or independent work), junior independent work (if applicable), service and general impressions made by the student on the faculty are also taken into consideration in honors calculation. Furthermore, to assure that a given class of honors remains consistent from year to year, the faculty compares students in one year with those who have received honors in recent years. Thus, every attempt is made to be fair to the student and also to maintain the quality of the honors being granted.

The following table shows honors distributions awarded by the Department over the last five years.

Honors	**High Honors**	**Highest Honors**
Percentage of Graduates	Percentage of Graduates	Percentage of Graduates
23.89%	9.44%	7.22%

If a student receives any form of academic honors, that fact is noted by public announcement on Class Day, printed in the Commencement program, and appears on the diploma.

HONOR SOCIETIES, AWARDS, AND PRIZES

In addition to academic honors, students are recognized for special achievement in other ways. Although the number and types of prizes and awards may vary from year to year, the following list is representative, but may not be complete.

Honor Societies

Phi Beta Kappa

All University seniors are eligible for membership in Phi Beta Kappa, probably the most prestigious as well as the oldest honor society. Each year, in May, it elects approximately the top 10% of the graduating class, ranking being dependent on the overall average for four years.

Tau Beta Pi

Tau Beta Pi is the engineering analog of Phi Beta Kappa. Each year in the spring it elects approximately the top 1/8 of the junior class and the top 1/5 of the senior class. While overall average up to the time of election is the primary criterion, Tau Beta Pi considers the personal character of the student and her/his service to the University in addition to scholarship.

Sigma Xi

Sigma Xi is an honorary research society whose members are largely from the sciences, including engineering. It has two classes of membership. Full membership is normally reserved for Ph.D. candidates, but seniors are eligible for Associate Membership. Nominees usually have excellent scholastic records, but the primary criterion for election is promise in research. Unlike Phi Beta Kappa and Tau Beta Pi, individual faculty members (rather than the Department as a whole) decide which students should receive the honor of election to Sigma Xi, which occurs in the spring of senior year. If membership in Sigma Xi interests you, speak to your senior thesis adviser in the spring term of your senior year.

Awards and Prizes in the Department of Chemical and Biological Engineering

The Department of Chemical and Biological Engineering has several awards to recognize the accomplishments of our undergraduate majors. Awards are made at the time of Class Day exercises just prior to Commencement.

AIChE Awards

The Central New Jersey Section of The American Institute of Chemical Engineers (AIChE) gives two awards every year.

The Award for Overall Excellence in Chemical Engineering, consisting of a certificate and a $500 prize, is presented to the top student of the graduating class.

The Ernest F. Johnson Distinguished Service Award, consisting of a certificate and a $500 prize, is awarded to that senior in the Department elected by her/his classmates "who has displayed exemplary character, service, spirit, and leadership from which her/his classmates have benefited".

The Richard K. Toner Thermodynamics Prize

This is awarded to the student(s) who has demonstrated superior scholarship, with special excellence in thermodynamics, who is planning a career in Chemical Engineering.

The Michelle Goudie '93 Senior Thesis Award, funded by the Du Pont Company

This award, established in the memory of Michelle Goudie '93 by the Du Pont Company, will be presented to a senior majoring in Chemical and Biological Engineering for outstanding accomplishment in the energy and environmental area. Nominations will be submitted by individual faculty members to the Department Representative, on the basis of students' participation in the Environmental Studies Program and/or senior thesis research. The award recipient will be chosen by vote of the full faculty of the Department.

Air Products Outstanding Senior Thesis Award

Selected by the faculty, this award is given annually to a graduating senior who has written an outstanding Senior Thesis in the materials area.

Sigma Xi Book Prize

The Sigma Xi Book Prize consists of a copy of the CRC handbook and is presented a student with high achievement in both coursework and senior thesis.

Awards Presented by the School of Engineering and Applied Science

Although not under the control of the Department, there are several prizes and awards given by the School of Engineering. Each of these has been awarded to a chemical and biological engineering major at least once in the previous ten years. The major awards are:

J. Rich Steers Award
To reward high scholastic performance that demonstrates potential for further engineering study and practice.

Tau Beta Pi Prize
For significant service to the School of Engineering and Applied Science.

Calvin Dodd MacCracken Senior Thesis Award
To recognizes the senior thesis that is most distinctive for its inventiveness and technical accomplishment.

Joseph Clifton Elgin Award
Awarded to a senior(s) who has done the most to advance the interest of the School of Engineering in the community at large.

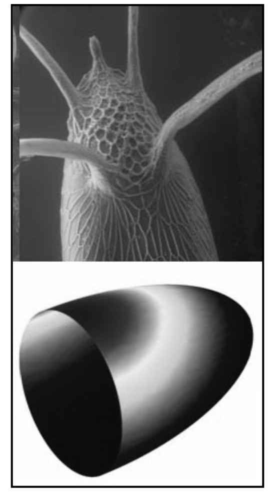
Lore von Jaskowsky Memorial Prize
Awarded to a senior who has a B or better average, has participated with noticeable élan in research that has resulted in a contribution to the field, whose interactions with other students, faculty, and staff has added to the quality of the university life, and who intends to pursue a career in engineering or applied science.

George J. Mueller Award
To honor the graduating senior who most evidently combined high scholarly achievement with quality of performance in intercollegiate athletics.

James Hayes-Edgar Palmer Prize in Engineering
Awarded to a senior who has manifested excellent scholarship, a marked capacity for leadership and promise of creative achievement in Engineering.

Awards Presented by the University

In addition to awards administered by the Department of Chemical and Biological Engineering and those awarded by the School of Engineering and Applied Science, there are awards made by the University for which all University seniors are eligible. A listing of all University prizes is given in the current issue of the Undergraduate Announcement. www.princeton.edu/ua



Top panel: The environmental SEM images of the eggshells of fruit fly species.

Bottom panel: The genesis of these morphologies is driven by gene expression in epithelial sheets

[Images courtesy of the Shvartsman Research Group]

ADVISING

Freshman Year

Members of the Chemical and Biological Engineering faculty and their colleagues from other engineering departments serve as advisors to freshman engineering students. Generally, students who have indicated an interest in chemical and biological engineering as a major will be assigned to a CBE faculty member. However, any student should feel free to consult any member of the Department of Chemical and Biological Engineering about her/his interests. Students signing into the CBE department at the end of the freshman year will be advised by the departmental representative and/or members of the CBE faculty undergraduate committee.

Sophomore-Senior Years

Sophomores are advised by professors within the Chemical and Biological Engineering department and remain as the student's adviser until graduation. By continuing with the same adviser for three years, each student should get to know one faculty member well and be comfortable with her/him.

The Departmental Representative

The Departmental Representative is the person most directly responsible for the undergraduate program. The Departmental Representative represents the Department on undergraduate matters before the Dean of the College and chairs the Department's Undergraduate Committee. If students have any problems which cannot be solved elsewhere, they should consult the Departmental Representative.

EXTRACURRICULAR ACTIVITIES

Although any engineering curriculum is difficult in terms of content and time requirements, Chemical and Biological Engineering students have always found time to engage in every form of extracurricular activities that the University offers—Sports, Musical Organizations, Journalistic Endeavors, the Student Volunteer Council, WPRB, the Triangle Club, Whig-Clio, Religious Functions, and any other that you can think of. Such participation need have no deleterious effect on your academic performance—indeed, most students are better off for the relaxation and stimulation that these extracurricular functions provide. A few programs of special interest to CBE students are given in the following list.

The Student Chapter of the American Institute of Chemical Engineers (AIChE)

Nearly all undergraduates join this student branch of the national professional society. New officers are elected each spring, and the student chapter is advised by a faculty member. Students are also welcome to attend meetings of the Central Jersey Section of the AIChE. These meetings consist of talks by practicing engineers on a wide variety of subjects. Consult the departmental bulletin boards for announcements of these meetings.

The Societies for Women Engineers (SWE), National Society of Black Engineers (NSBE), and the Society of Hispanic Professional Engineers (SHPE)

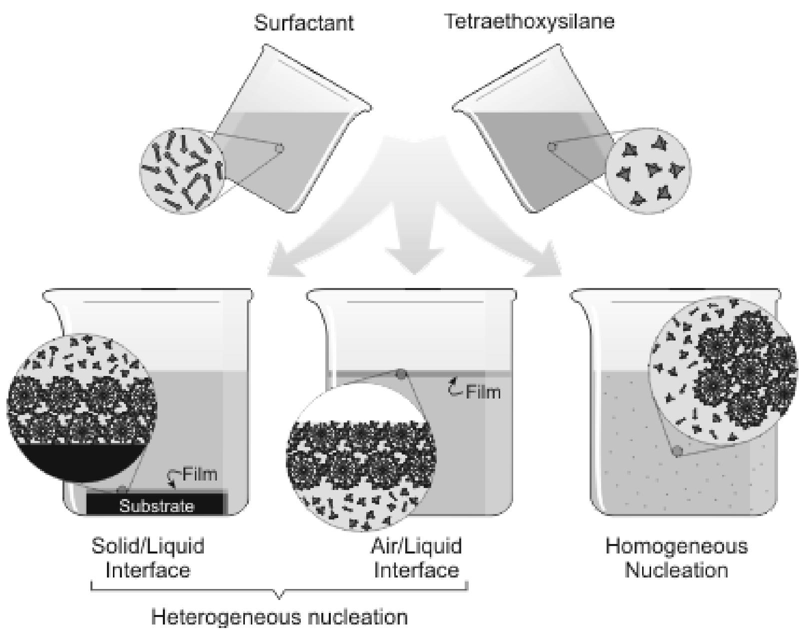
These three societies provide programs of interest for the groups indicated in their titles.

The Engineering Council

The E-Council is a representative body of the School which sponsors and promotes activities of general interest and benefit to engineering undergraduates. It also provides an opportunity for exchange of ideas between the various engineering societies (such as AIChE) and Princeton University. It is made up of four officers and unlimited members. It produces Frosh Help, the engineering student course guide, the physics guide, and the graduate school guide. It also gives out teaching awards, arranges lunches for first-year students, holds forums, and provides study breaks.

International Association for Hydrogen Energy

Undergraduate students interested in energy join this student group with a main objective to promote hydrogen as a sustainable energy carrier for the future. The group will also strive to connect Princeton University students, especially those with an interest in energy technology or public policy, to the worldwide opportunities and professional mentorships sponsored by IAHE. As one of the organization's pioneering student chapters in US, IAHE-PU will aim to engage the campus with learning more about hydrogen energy, its potential, its limitations, and the open questions motivating today's cutting-edge research on alternative energy. The group aspires to become an active member in the university's Sustainability Plan, and to bring new technological perspectives to the existing efforts on campus.



Generalized mechanisms for forming structured silica through the interaction of a structure-directing agent (surfactant) and silicon alkoxide (TEOS).

[Image courtesy of the Aksay Research Group]

AFTER GRADUATION — THEN WHAT?

With academic pressures being what they are, it is not surprising that students reach senior year without giving serious thought to their future careers. Some, like those interested in medicine, must, of course, reach a decision much earlier, and it will help all students if they give some attention to this important matter during their early academic years.

The Department sponsors a regular series of seminars which are held on the average of once a week. While they are intended primarily for faculty and graduate students, all persons are welcome. We encourage our students to scan the programs for seminars of interest.

Not later than junior year, each of you should register with Career Services. That office can be of great help to you in planning your career and in meeting professional representatives who come to Princeton recruiting for both permanent and summer employment, as well as internships. All recruiting and scheduling is handled through Career Services. The Department lends assistance by talking with company representatives and writing letters of recommendation. Career Services also can assist those contemplating graduate study. They also have information on companies employing chemical engineers, whether or not that company comes to Princeton for interviews.

Summer work is a good way of sharpening the focus of your interests. Most juniors get interesting (well-paying) summer jobs either on their own or with the aid of Career Services. A summer internship is well worth the effort for students who get one. Students should check the bulletin boards and department mailboxes for opportunities.

THE FACULTY

Faculty members are listed alphabetically, with their rank and general fields of interest. For their current undergraduate teaching activity, see the *Undergraduate Announcement*, www.princeton.edu/ua.

Ilhan A. Aksay: Professor; Ph.D. University of California, Berkeley, 1973. Processing and properties of ceramic materials; biomimetic processing; hierarchically structured materials; high-temperature superconductors.

José L. Avalos: Assistant Professor; Ph.D. Johns Hopkins University, 2004. Metabolic engineering, organelle engineering, synthetic biology, systems biology, structural biology and protein engineering

Jay B. Benziger: Professor; Ph.D. Stanford University, 1979. Catalysis and Reaction Engineering; clean fuels; PEM fuel cells; large-scale liquid purification; novel material deposition processes.

Clifford P. Brangwynne: Assistant Professor; Ph.D. Harvard University, 2007. Patterning in Developing Embryos; Physical Properties and Function of RNA/Protein Bodies; Architecture and Dynamics of the Cytoskeleton.

Mark P. Brynildsen: Assistant Professor; Ph.D. University of California, Los Angeles, 2008. Host-pathogen Interactions; Bacterial Persistence; Biofilms.

Pablo G. Debenedetti: Dean of Research and Class of 1950 Professor in Engineering and Applied Science; Ph.D. Massachusetts Institute of Technology, 1985. Thermodynamics and statistical mechanics; theory of liquids and glasses; supercritical fluids.

Yannis G. Kevrekidis: Pomeroy and Betty Perry Smith Professor in Engineering; Ph.D. University of Minnesota, 1986. Nonlinear system identification and control; dynamics of chemical reactors; computer modeling and applied mathematics.

Bruce E. Koel: Professor; Ph.D. University of Texas, Austin, 1981. Structure, Reactivity, and Catalysis of Bimetallic Pt Alloys; Characterizing Reactions of Iron Nanoparticles; Characterization of Novel PEM Fuel Cell Electrodes; Development of Rutherford Backscattering (RBS) as a Probe of Liquid-Solid Interfaces.

A. James Link: Departmental Representative and Associate Professor; Ph.D. California Institute of Technology, 2006. Peptide and protein engineering, chemical biology, applied microbiology

Yueh-Lin (Lynn) Loo: Theodora D. ’78 and William H. Walton III ’74 Professor in Engineering; Ph.D. Princeton University, 2001. Organic and polymer electronics; soft lithography; self-assembled monolayers on metal and semiconductor surfaces; block copolymers.

Celeste M. Nelson: Director of Graduate Studies, Director of the Program in Engineering Biology, and Associate Professor; Ph.D. Johns Hopkins University, 2003. Mammalian tissue, morphogenesis/morphodynamics; microfrabrication/bioMEMS for tissue engineering; cell adhesion and mechanics.

Athanassios Z. Panagiotopoulos: Susan Dod Brown Professor of Chemical and Biological Engineering; Ph.D. Massachusetts Institute of Technology, 1986. Molecular simulation methods; phase transitions of ionic, polymeric and surfactant systems; self-assembled nanoscale materials.

Rodney D. Priestley: Associate Professor; Ph.D. Northwestern University, 2008. Polymer Science and Engineering, Nanoscale Materials Characterization, Supramolecular Polymers, Healing and Responsive Materials, Polymeric Membranes.

Robert K. Prud'homme: Professor; Ph.D. University of Wisconsin, 1978. Rheology and rheo-optics of structured fluids; characterization and application of natural polymers; materials processing with complex fluids.

Richard A. Register: Chairman and Eugene Higgins Professor of Chemical and Biological Engineering; Ph.D. University of Wisconsin, 1989. Morphology and rheology of multiphase polymeric materials; polymer structure-processing-property relationships.

William B. Russel: Dean of The Graduate School and Arthur W. Marks '19 Professor of Chemical and Biological Engineering; Ph.D. Stanford University, 1973. Colloidal materials; polymer-particle interactions; colloidal crystallization in microgravity; rheology of complex fluids.

Stanislav Y. Shvartsman: Professor; Ph.D. Princeton University, 1999. Reaction, transport and pattern formation in biological systems; dynamics and control of cell communication networks.

Sankaran Sundaresan: Norman John Sollenberger Professor in Engineering; Ph.D. University of Houston, 1980. Dynamics of two-phase flows, trickle-bed reactors and fluidized beds; environmentally benign chemical processing.

Associated Faculty

Ian C. Bourg; Assistant Professor of Civil and Environmental Engineering; Ph.D. University of California, Berkeley, 2004; Natural and Engineered Clay Barriers, Geologic Carbon Sequestration, Kinetic Isotope Effects at Water Surfaces.

Emily A. Carter: Gerhard R. Andlinger Professor of Mechanical and Aerospace Engineering, and Founding Director of Gerhard R. Andlinger Center for Energy and the Environment; Ph.D. California Institute of Technology, 1987; Quantum-mechanics-based theories of molecular and materials behavior.

Sabine Petry: Assistant Professor of Molecular Biology; Ph.D. University of Cambridge, 2007; Molecular Architecture and Function of the Microtubule Cytoskeleton.

George W. Scherer: William L. Knapp '47 Professor of Civil and Environmental Engineering; Ph.D. Massachusetts Institute of Technology, 1974; Biopreservations; Art and Monument Conservation; Flow in Porous Media; Ceramics and Glasses.

Howard A. Stone: Donald R. Dixon '69 and Elizabeth W. Dixon Professor in Mechanical and Aerospace Engineering; Ph.D. California Institute of Technology, 1988; Fluid Dynamics and Transport Processes; Complex Fluids; Colloidal Hydrodynamics; Microfluidics; Cellular-scale

Hydrodynamics; Hydrodynamics Related to Biofilms; Biofilm Formation and Characterization; Drying and Transport in Natural Materials.

Jared E. Toettcher: Assistant Professor of Molecular Biology; Ph.D. Massachusetts Institute of Technology, 2009; Cellular Optogenetics.

Claire E. White: Assistant Professor of Civil and Environmental Engineering; Ph.D. University of Melbourne, 2010; Low-CO_2 Concrete, Mineralization During CO_2 Capture**.**

LABORATORY SAFETY INFORMATION

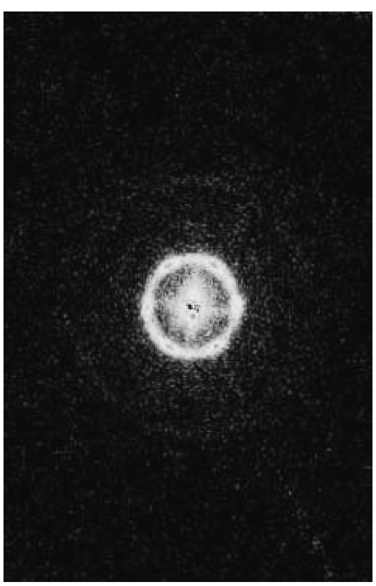
Core and Design Labs

The Undergraduate Teaching Laboratories (Core Labs) support the course CBE 346, a course in hands-on practice of engineering, including experiment work, class work associated with introduction to laboratory safety, data analysis, process hardware and process dynamics and development of technical communication skills. The laboratory houses experimental stations along with permanently available instrumentation.

The Undergraduate Design Laboratory supports the course CBE 442 Design, Synthesis, and Optimization of Chemical Processes. The A124 classroom has been specifically equipped to support the Design Course.

To work in the laboratories it is required that all students take the University sponsored Lab Safety course. This is included as part of the CBE 346 course in the junior year. Students who chose to work in departmental labs earlier must arrange to take the Lab Safety course at one of the offerings during the academic year.

Should any incident occur in a lab in which a student is injured, immediately call 911 on a campus phone or 609-258-1000 on a cell phone to alert Public Safety. In the event of any incident that results in a possible overexposure to a chemical, regardless of whether any signs or symptoms of exposure are noted or whether the laboratory worker seeks medical attention, the student should immediately contact the Department Manager in room A215 (ext. 8-4650) and the Department Safety Officer Professor Prud'homme in room A301 (ext. 8-4577).



Two-dimensional small-angle x-ray scattering patterns reveal the nanostructure of two styrene-diene-styrene triblock copolymers which have been aligned through channel die compression.

[Image courtesy of Sasha Meyers and Professor Richard A. Register]

THE MICHELLE GOUDIE ’93 UNDERGRADUATE SUMMER FELLOWSHIP IN ENVIRONMENTAL STUDIES

The Fellowship

The Goudie ’93 Fellow will engage in independent research in the area of environmental studies during the summer under the supervision of a faculty member in the Department of Chemical and Biological Engineering or other appropriate department at Princeton. The CBE department will award the fellowship to a student each summer. The fellowship consists of a typical summer stipend, approximately $5,500 ($550/week over 10 weeks), plus research supplies. US citizenship is not required.

The Application

Please write a one-page narrative about your educational background and interests, and describe what research you would be interested in working on if you are selected to receive the Goudie ’93 Fellowship. Prior to submitting your application, conversations with specific faculty members about a research topic in the area of environmental studies that you would work on should be addressed in your narrative. Submit your narrative to the Department Manager in A215. The deadline for applying is usually in mid-March.

The Process

All applications will be reviewed by the undergraduate committee. Recommendations from the committee will be given to the Department Chair, who along with the Department Representative, will select the winner.

The winner will be announced by early April. The recipient of the Goudie ’93 Summer Fellowship will work under the supervision of a faculty member at Princeton University. The faculty assignment will be determined by the committee reviewing the applications.

The Michelle Goudie ’93 Undergraduate Summer Fellowship is only open to rising seniors in the Chemical and Biological Engineering department and is sponsored by the DuPont Company.

THE REINER G. STOLL UNDERGRADUATE SUMMER FELLOWSHIP IN CHEMICAL ENGINEERING

The Fellowship

The Stoll Fellow will engage in independent research during the summer under the supervision of a faculty member in the Department of Chemical and Biological Engineering. The Department awards the fellowship to one or two students each summer. The fellowship consists of a typical summer stipend, approximately $5,500 ($550/week over 10 weeks), plus research supplies. US citizenship is not required.

The Application

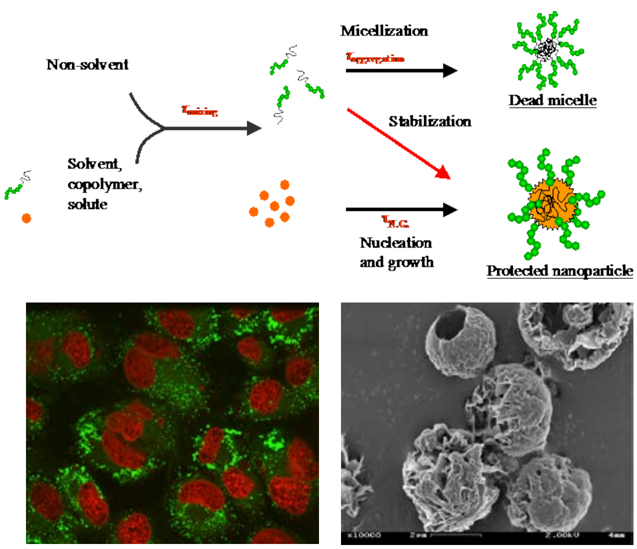
Please write a one-page narrative about your educational background and interests, and describe what you would be interested in working on if you are selected to receive the Stoll Fellowship. Prior to submitting your application, conversations with specific faculty members about a research topic that you would work on should be addressed in your narrative. Submit your narrative to the Department Manager in A215. The deadline for applying is usually in mid-March.

The Process

All applications will be reviewed by the undergraduate committee. Recommendations from the committee will be given to the Department Chair, who along with the Departmental Representative, will select the winner.

The winner will be announced by early April. The recipient of the Stoll Summer Fellowship will work under the supervision of a faculty member in Chemical and Biological Engineering. The faculty assignment will be determined by the committee reviewing the applications.

The Reiner G. Stoll Summer Fellowship is open to rising juniors in the Chemical and Biological Engineering department and is sponsored by The Camille and Henry Dreyfus Foundation, Inc.



Nanoparticle formation and the applications for cancer therapy and aerosol drug delivery.

[Image courtesy of Professor Robert K. Prud'homme}

MISCELLANEOUS REMARKS

Student Mail

There are individual mailboxes for all sophomore, junior, and senior chemical and biological engineering students outside Room A201/203. Upperclassmen especially should check this box regularly. Companies frequently send information about jobs to students in care of the Department. This mail, graded problem sets, and other material for a student's attention will be transmitted to the student by way of this mailbox.

Undergraduate Student Travel

For any travel that has to do with research, academic course work or extracurricular activities require students to register the trip on the University Travel Database. Refer to http://www.princeton.edu/campuslife/travel/

Undergraduate Lounge

A lounge for chemical and biological engineering undergraduates is located in A203. This lounge is a focal point for undergraduate informal study groups (and study breaks). It is the responsibility of the students to keep the lounge clean and in order.

Conclusion

While an attempt has been made to anticipate and answer those questions that students are likely to ask, there are almost certainly going to be some omissions. The *Undergraduate Announcement*, www.princeton.edu/ua is a good source of further information on University regulations such as the Honor Code, scholastic requirements, the University Scholar Program, etc., which affect all students and not just those in this Department.

Any further questions may be addressed to the Departmental Representative, Professor A. James Link, Hoyt Lab 207, or the Undergraduate Administrator, Julie Sefa, Room A201, Engineering Quadrangle.

If you have any question about our program prior to applying, or have difficulty accessing our website, please address inquiries to: Undergraduate Studies, Department of Chemical and Biological Engineering, Princeton University, Princeton, NJ 08544-5263, USA, or by fax at (609) 258-0211. By telephone, contact the Undergraduate Administrator at (609) 258-4572, or by e-mail at cbeug@princeton.edu.

Laboratory Checkout Statement

For Chemical and Biological Engineering Students doing Experimental Work

This form, signed and completed, must be returned to the undergraduate office, A-201, by students who have done experimental work in a laboratory. Failure to turn in this form will result in an Incomplete grade for CBE 351, CBE 352, & CBE 454 Senior Thesis.

All chemicals used must be properly labeled and/or disposed of. All equipment and supplies should be left in good condition. If undisposed samples are being passed on to another graduate student, undergraduate or postdoc, the name of that person must be noted below. The student's laboratory should be inspected by the thesis adviser and a graduate student or postdoc from the lab who has been working with the senior, who should make a recommendation and sign below.

Date:

Undergraduate Student Name:

Forwarding Address:

Telephone Number:

Adviser:

(*) Student Continuing Work (if applicable):

Adviser and Graduate Student/Postdoc Recommendation:

Adviser Signature:

Lab Member Signature:

(*) All samples to be passed on to me are labeled to my satisfaction

Continuing Student Signature:

Chemical and
Biological
Engineering

PRINCETON

School of
Engineering
and Applied
Science