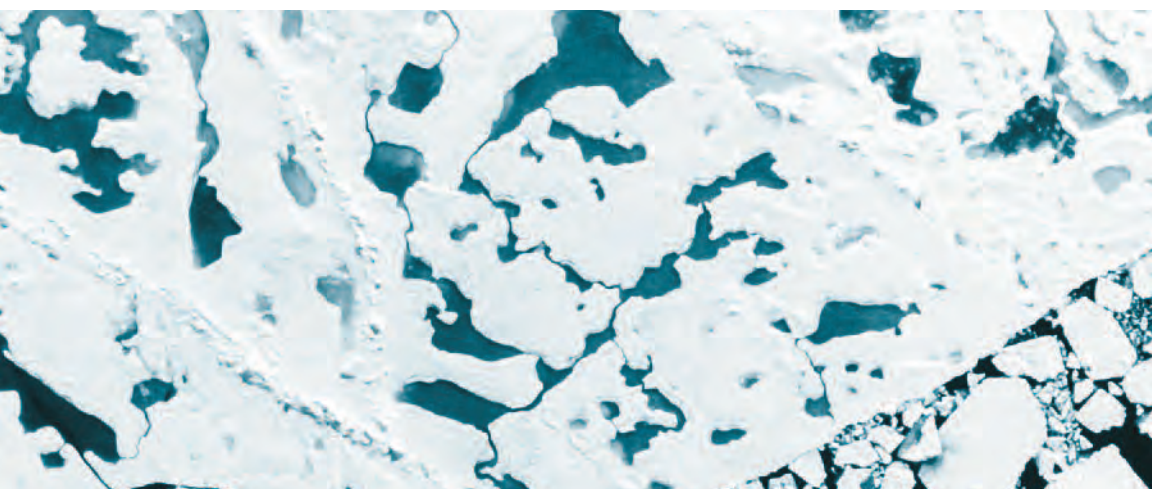


2014  
2015

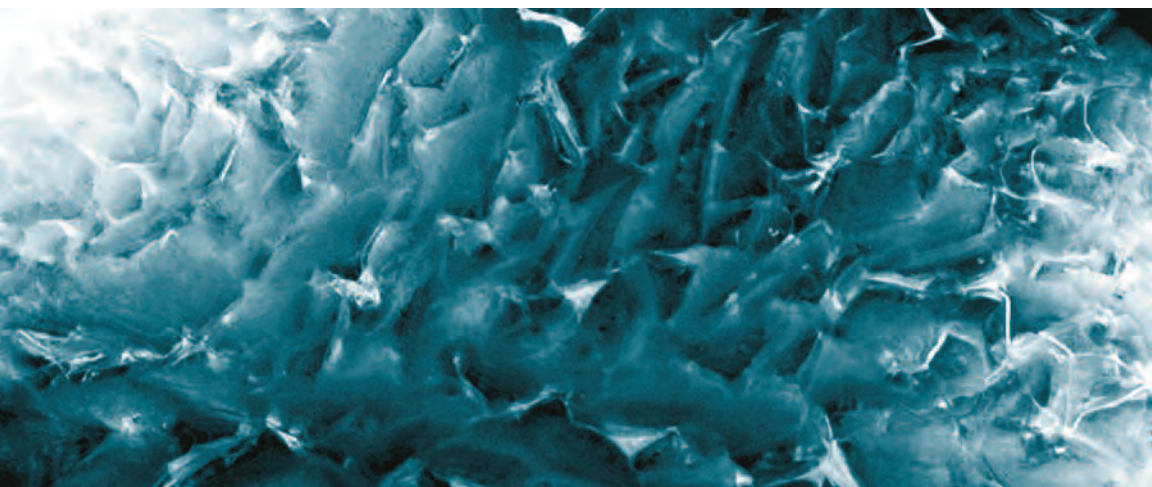


Guide to  
Programs  
and  
Courses

Thayer School of Engineering  
AT DARTMOUTH

[engineering.dartmouth.edu](http://engineering.dartmouth.edu)

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Above: Optical microscopy image of frozen deionized water with ice-shaping additives. Image by former research associate Shih-Feng Chou of Professor Ulrike Wegst's lab.

Front Cover: Melting Arctic sea ice. Photo by Adjunct Professor Donald Perovich.

Back Cover: Scanning electron microscopy back scatter electron image of a tin monoxide (SnO) thin film of needle-like nanostructures. These thin films can be used as transparent, light-scattering electrodes for photovoltaics and have applications in other optoelectronic devices. Image courtesy of M.S. graduate Andrew Wong '12 Th'14, working in Professor Jifeng Liu's lab.

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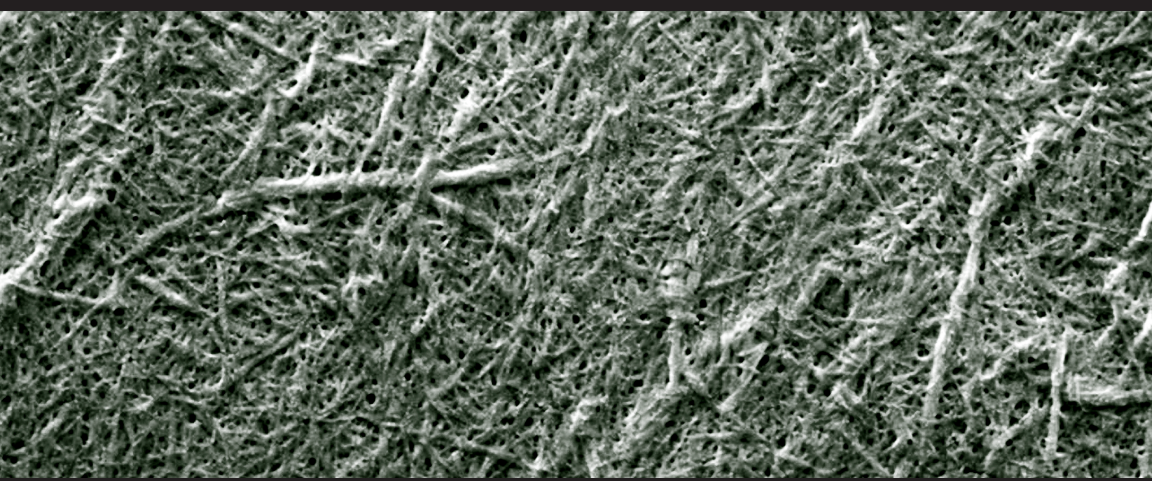
# Academic Calendar 2014-2015

[engineering.dartmouth.edu/academics/calendar/](http://engineering.dartmouth.edu/academics/calendar/)

FALL TERM 2014	
September 11–12, Thursday–Friday	Orientation for new students
September 14, Sunday	Fall term check-in
September 15, Monday	Fall term classes begin at 7:45 a.m.; Convocation at 3:15 p.m.
September 23, Tuesday	Final day for delayed check-in
October 17–18, Friday–Saturday	Homecoming
November 18, Tuesday	Fall classes end at 5:20 p.m.; pre-examination break begins
November 21–26, Friday–Wednesday	Fall term examinations
WINTER TERM 2015	
January 4, Sunday	Winter term check-in
January 5, Monday	Winter term classes begin at 7:45 a.m.
January 13, Tuesday	Final day for delayed check-in
January 19, Monday	Observance of Martin Luther King, Jr. Day (Classes moved to x-periods except 3A classes, which move to the 3B period on Tues., Jan. 20)
February 6, Friday	Carnival holiday (classes moved to x-periods)
March 10, Tuesday	Winter term classes end at 5:20 p.m.; pre-examination break begins
March 13–17, Friday–Tuesday	Winter term examinations
SPRING TERM 2015	
March 29, Sunday	Spring term check-in
March 30, Monday	Spring term classes begin at 7:45 a.m.
April 7, Tuesday	Final day for delayed check-in
May 25, Monday	Memorial Day (College holiday) No classes;
June 2, Tuesday	Spring term classes end at 5:50 p.m.
June 3–4, Wednesday–Thursday	Pre-examination break
June 5–9, Friday–Tuesday	Spring term examinations
June 13, Saturday	Thayer School Investiture Ceremony
June 14, Sunday	Dartmouth Commencement Day
SUMMER TERM 2015 (TENTATIVE)	
June 24, Wednesday	Summer term check-in
June 25, Thursday	Summer term classes begin at 7:45 a.m.
June 27, Saturday	Special day of classes 8:00 a.m.–12:50 p.m.; courses regularly held in the 10-sequence meet at 8:00 a.m.; in 11-, at 9:15 a.m.; in 12-, at 10:30 a.m.; and in 2-, at 11:45 a.m. Courses regularly held in other time sequences do not meet.
July 6, Monday	Final day for delayed check-in
August 26, Wednesday	Summer term classes end at 5:20 p.m.; pre-examination break begins
August 29–September 1, Saturday–Tuesday	Summer term examinations



# Faculty



Freeze-cast self-assembled chitin nanofiber mat. Image courtesy of former research associate Shih-Feng Chou, working in Professor Ulrike Wegst's lab.

# Faculty

[engineering.dartmouth.edu/people/faculty/](http://engineering.dartmouth.edu/people/faculty/)

## EMERITI

**Alvin Omar Converse, Ph.D.**

Professor of Engineering, Emeritus

**Robert C. Dean, Jr., Sc.D**

Adjunct Professor of Engineering, Emeritus

**Robert J. Graves, Ph.D.**

John H. Krehbiel Sr. Professor for Emerging Technologies, Emeritus

**Charles Edgar Hutchinson, Ph.D.**

Dean of Thayer School, Emeritus

John H. Krehbiel Sr. Professor for Emerging Technologies, Emeritus

**Francis E. Kennedy Jr., Ph.D.**

Professor of Engineering, Emeritus

**Horst J. Richter, Dr.-Ing.**

Professor of Engineering, Emeritus

**Bengt Ulf Östen Sonnerup, Ph.D.**

Sydney E. Junkins 1887 Professor, Emeritus

**Victor F. Petrenko, D.Sc.**

Research Professor, Emeritus

**Graham B. Wallis, Ph.D.**

Sherman Fairchild Professor, Emeritus

## ENDOWED PROFESSORSHIPS

Sue and John Ballard '55 TT'56 Professorship  
William Lotko

George Austin Colligan Distinguished Professorship  
Erland M. Schulson

Sherman Fairchild Professorship  
Ian Baker

Dorothy and Walter Gramm Professorship  
George Cybenko

Sydney E. Junkins 1887 Professorship  
Elsa Garmire

MacLean Professorship  
Daniel R. Lynch

Robert A. Pritzker Chair in Biomedical Engineering  
Keith Paulsen

Paul E. and Joan H. Queneau Distinguished Professorship  
in Environmental Engineering Design  
Lee R. Lynd

Myron Tribus Professorship in Innovation  
John P. Collier

## REGULAR FACULTY

**Margie Ackerman** Ph.D.  
Assistant Professor

**Mary R. Albert** Ph.D.  
Professor

**Ian Baker** D.Phil  
Sherman Fairchild Professor  
Senior Associate Dean for Academic Affairs

**Mark E. Borsuk** Ph.D.  
Associate Professor

**John P. Collier** D.E.  
Myron Tribus Professor in Innovation

**Benoit Cushman-Roisin** Ph.D.  
Professor  
Interim Director, M.E.M. Program

**George Cybenko** Ph.D.  
Dorothy and Walter Gramm Professor

**Scott C. Davis** Ph.D.  
Assistant Professor

**Solomon G. Diamond** Ph.D.  
Associate Professor

**Brenden P. Epps** Ph.D.  
Assistant Professor

**Eric Fossum** Ph.D.  
Professor

**Harold J. Frost** Ph.D.  
Associate Professor

**Elsa Garmire** Ph.D.  
Sydney E. Junkins 1887 Professor

**Tillman U. Gerngross** Ph.D.  
Professor

**Michael Gerst** Ph.D.  
Assistant Professor

**Karl Griswold** Ph.D.  
Associate Professor

**Ryan J. Halter** Ph.D.  
Assistant Professor

**Eric W. Hansen** Ph.D.  
Associate Professor

**Alexander Hartov** Ph.D.  
Professor

**Joseph J. Helble** Ph.D.  
Dean and Professor

**Jane E. Hill** Ph.D.  
Associate Professor

**Songbai Ji** D.Sc.  
Associate Professor

**Shudong Jiang** Ph.D.  
Associate Professor

**Stephen C. Kanick** Ph.D.  
Assistant Professor

**Venkataramanan Krishnaswamy** Ph.D.  
Assistant Professor

**Ronald C. Lasky** Ph.D.  
Professor  
Director, Cook Engineering Design Center

**Christopher G. Levey** Ph.D.  
Associate Professor  
Director, Microengineering Laboratory  
Director, Instructional Laboratories  
Adjunct Professor of Physics and Astronomy

**Jifeng Liu** Ph.D.  
Assistant Professor

**William Lotko** Ph.D.  
Sue and John Ballard '55 TT'56 Professor

**Daniel R. Lynch** Ph.D.  
MacLean Professor

**Lee R. Lynd** D.E.  
Paul E. and Joan H. Queneau Distinguished Professor in Environmental  
Engineering Design  
Adjunct Professor of Biological Sciences

**Vicki May** Ph.D.  
Associate Professor

**Paul M. Meaney** Ph.D.  
Professor

**Rachel Obbard** Ph.D.  
Assistant Professor

**Kofi Odame** Ph.D.  
Assistant Professor

**Keith D. Paulsen** Ph.D.  
Robert A. Pritzker Chair in Biomedical Engineering  
Professor of Radiology, Geisel School of Medicine  
Director, Advanced Imaging Center, Dartmouth-Hitchcock Medical Center  
Co-Director, Cancer Imaging and Radiobiology Research Program, Norris Cotton  
Cancer Center

**Minh Q. Phan** Ph.D.  
Associate Professor

**Brian W. Pogue** Ph.D.  
Professor  
Director, M.S. and Ph.D. Programs

**Laura R. Ray** Ph.D.  
Professor

**Peter J. Robbie** M.F.A.  
Associate Professor

**Eugene Santos Jr.** Ph.D.  
Professor

**Erland M. Schulson** Ph.D.  
George Austin Colligan Distinguished Professor  
Chair, Engineering Sciences Department  
Director, B.E. Program  
Director, Ice Research Laboratory

**Xiongjun Shao** Ph.D.  
Assistant Professor

**Simon G. Shepherd** Ph.D.  
Associate Professor

**Fridon Shubitidze** Ph.D.  
Associate Professor

**Jason Stauth** Ph.D.  
Assistant Professor

**Charles R. Sullivan** Ph.D.

Professor

**Stephen Taylor** Ph.D.

Professor

**B. Stuart Trembly** Ph.D.

Associate Professor

**Douglas W. Van Citters** Ph.D.

Assistant Professor

**Vikrant Vaze** Ph.D.

Assistant Professor

**Ulrike G.K. Wegst** Ph.D.

Associate Professor

**John X.J. Zhang** Ph.D.

Professor



## ADJUNCT AND VISITING FACULTY

**Kenneth R. Baker** Ph.D.

Nathaniel Leverone Professor of Management, Tuck School of Business  
Adjunct Professor of Engineering

**Benjamin Barrowes** Ph.D.

Research Physicist, U.S. Army Cold Regions Research and Engineering Laboratory  
Adjunct Assistant Professor of Engineering

**Petra Bonfert-Taylor** Ph.D.

Visiting Associate Professor

**Jay C. Buckey Jr.** M.D.

Professor of Medicine, Geisel School of Medicine  
Adjunct Professor of Engineering

**Chi-Yang Cheng** Ph.D.

Professor of Medicine, Geisel School of Medicine  
Adjunct Associate Professor of Engineering

**David Cole** Ph.D.

Research Civil Engineer, U.S. Army Cold Regions Research and Engineering Laboratory  
Adjunct Professor of Engineering

**Zoe Courville** Ph.D.

Research Mechanical Engineer, U.S. Army Cold Regions Research and  
Engineering Laboratory  
Adjunct Assistant Professor

**Hamid Dehghani** Ph.D.

Adjunct Assistant Professor of Engineering  
Senior Lecturer, School of Computer Science, University of Birmingham, UK

**Eugene Demidenko** Ph.D.

Professor of Community and Family Medicine, Geisel School of Medicine  
Adjunct Professor of Engineering

**Ursula J. Gibson** Ph.D.

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**Barjor Gimi** Ph.D.

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**Oliver Goodenough** J.D.

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Adjunct Professor of Engineering

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Director, The Brain Engineering Laboratory  
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**Richard M. Greenwald** Ph.D.

Co-Founder and President, Simbex, Lebanon, N.H.  
Co-Founder, iWalk, Cambridge, Mass.  
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**Atsushi Hamasaki** Ph.D.

Visiting Associate Professor

**John Heaney** M.D.

Professor of Surgery, Geisel School of Medicine  
Adjunct Professor of Engineering

**Christopher D. Herring**

Mascoma Corporation  
Adjunct Associate Professor

**P. Jack Hoopes** Ph.D.

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Adjunct Professor of Engineering  
Director, Surgery and Radiation Research Laboratories  
Co-Director, NCCC Cancer Nanotechnology Working Group

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**Frederic Leblond** Ph.D.

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**Edward J. March** Ph.D.

Interim Co-director MEM Program  
Adjunct Professor of Engineering

**Michael B. Mayor** M.D.

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Adjunct Professor of Engineering

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**Joseph M. Rosen** M.D.

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Adjunct Professor of Engineering

**Kimberly Samkoe** Ph.D.

Department of Surgery, Dartmouth-Hitchcock Medical Center  
Adjunct Assistant Professor

**Axel Scherer** Ph.D.

Distinguished Visiting Professor of Engineering

**Anatoly V. Streltsov** Ph.D.

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**Harold M. Swartz** Ph.D.

Professor of Radiology and of Community and Family Medicine and of Physiology,  
Geisel School of Medicine  
Adjunct Professor of Engineering

**Elijah Van Houten** Ph.D.

Senior Lecturer, University of Canterbury  
Adjunct Associate Professor of Engineering

**John Weaver** Ph.D.

Professor of Radiology, Geisel School of Medicine  
Adjunct Associate Professor

**Yongsup Yun** Ph.D.

Visiting Assistant Professor

## LECTURERS

**Daniel C. Cullen** Ph.D.

Project Lab, Materials Lab, Fluids Lab Manager

**Kendall Hoyt** Ph.D.

Assistant Professor of Medicine, Geisel School of Medicine

**Mark Laser** Ph.D.

Research Scientist

**Steven Peterson** M.S.

Independent Consultant

**Amanda Plagge** Ph.D.

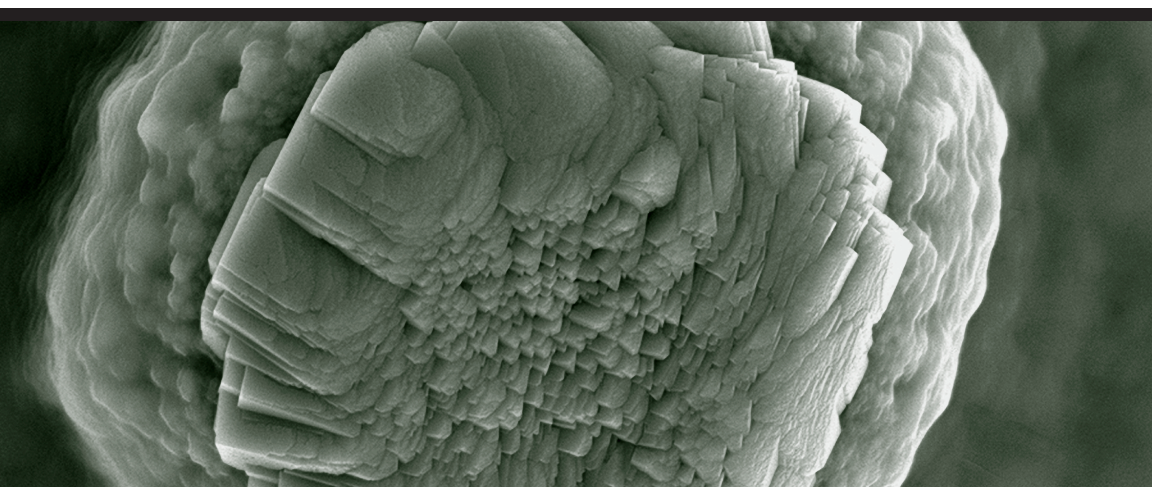
Research Associate

**Markus Testorf** Ph.D.

**John D. Wilson** M.Arch.

Senior Lecturer, Studio Art

# Undergraduate Studies



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# Undergraduate Studies

[engineering.dartmouth.edu/academics/undergraduate/](http://engineering.dartmouth.edu/academics/undergraduate/)

The goal of all engineering sciences programs is to educate students to apply technological skills to help meet societal needs, using concepts from a range of engineering disciplines.

## ENGINEERING DEGREE PROGRAMS

**Bachelor of Arts (A.B.)** The engineering sciences major requires 7 prerequisites in mathematics and science, 9-10 courses in engineering sciences, and all College liberal arts requirements.

**Bachelor of Engineering (B.E.)** The B.E. degree, a professional degree recognized by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, Telephone: (410) 347-7700, requires 9-10 engineering sciences courses beyond the A.B. degree.

**Dual-Degree Program.** Students from colleges and universities other than Dartmouth can combine a bachelor's degree from their home institution with a B.E. from Thayer School. Information about the dual-degree program is at: [engineering.dartmouth.edu/academics/undergraduate/dual/](http://engineering.dartmouth.edu/academics/undergraduate/dual/)

## PREREQUISITES

All engineering sciences majors, minors, and modified majors take 7 courses in mathematics, physics, computer science, and chemistry. First-year students should take the placement test in mathematics during orientation week. Unless otherwise prohibited, prerequisites may be taken under the Non-Recording Option.

## ENGINEERING SCIENCES CURRICULUM

Students interested in the engineering sciences major or modified major should work with a faculty advisor to plan their study program early. Those interested in the combined A.B./B.E. program should use the B.E. Program Plan to plan their course of study for both degrees.

The engineering sciences curriculum immerses students in the work of applying engineering theory to practical problems.

- Common core courses emphasize an integrated approach to problem solving, project management, and systems analysis
- Distributive core courses address fundamental concepts of engineering
- Gateway courses introduce students to specific engineering disciplines

In all courses, students practice critical thinking and communications, skills that mark the highly valued professional engineer.

## ADVANCE PLANNING FOR THE M.E.M. DEGREE

A large number of A.B. students plan their course of study to include the B.E. degree and then the Master of Engineering Management (M.E.M.) degree. The M.E.M. program combines engineering and management courses taught by Thayer School and Tuck School faculty and includes an industry internship (see page 44).

Planning your course selection with your faculty advisor early in your A.B. studies can enable you to complete the A.B., B.E., and M.E.M. programs in 6 years. **A.B. students planning to do the M.E.M. degree should take two engineering sciences electives beyond what is required for the major.** Delaying your planning until after you have entered the B.E. program will likely lengthen the completion time for the combined 3 degrees beyond 6 years. Applying for admission to the M.E.M. program while in the A.B. is also possible.

See page 47 for a typical course sequence for completing the A.B., B.E., and M.E.M. degrees in 6 years.

## GRADE STANDARDS

Students taking courses for either the A.B. or B.E. degree are assigned grades ranging from A (for excellent) to E (not acceptable for degree credit). A “plus” or “minus” appended to a grade indicates a level slightly greater or lesser than the norm for that category. Grade point values are A = 4; A- = 3.67; B+ = 3.33; etc. The following guidelines offer general criteria for evaluation and grading, with “plus” or “minus” designations indicating that in the opinion of the instructor, the student has performed at a level slightly higher or lower than the norm for the category.

- A: Excellent mastery of course material
- B: Good mastery of course material
- C: Acceptable mastery of course material
- D: Deficient in mastery of course material
- E: Serious deficiency in mastery of course material.

A.B. candidates must maintain an average of 2.0 in courses for the major. B.E. candidates must maintain a grade average of C+ or better for the 9 courses required for the degree. No more than 2 courses may have a grade less than C. Students who fail to maintain a C+ average in any term are placed on probation.

B.E. candidates are required to meet standards, in addition to earning a minimum grade point average of 2.33:

- no more than three (3) courses with grades below C, where C- is below C, will be counted towards the B.E. degree
- this number of 3 will be computed from all courses taken to satisfy B.E. requirements, excluding the prerequisites to the major in engineering sciences.

### **HONORS PROGRAM**

[engineering.dartmouth.edu/academics/undergraduate/ab/honors/](http://engineering.dartmouth.edu/academics/undergraduate/ab/honors/)

A.B. students who have an overall grade point average of 3.0 with a 3.33 grade point average in the major are eligible for the Honors Program in Engineering Sciences. Applications are accepted between the second week of the fall term in the junior year and the second week of the winter term in the senior year. The honors project, either an experimental or a theoretical investigation, generally begins in ENGS 87 Undergraduate Investigations; the project itself, part of ENGS 88 Honors Thesis, includes a written thesis and an oral presentation.

Students who complete the Honors Program with a B+ average or better and have a grade point average of 3.33 or higher in the major receive a degree with “Honors in Engineering Sciences.” A degree with “High Honors in Engineering Sciences” is awarded to students who, in addition to the above, have taken two Engineering Sciences courses beyond those required for the major (excluding courses under ENGS 20 and ENGS 87), have attained a grade point average of 3.50 in all engineering sciences courses, and have completed outstanding independent work.

### **ACADEMIC HONOR**

All students, upon matriculation, sign an agreement to abide by the honor principles established by Dartmouth College and Thayer School. For A.B. candidates, the full statement of academic honor is at:  
[dartmouth.edu/~uja/honor/](http://dartmouth.edu/~uja/honor/)

For B.E. candidates, the full statement is in the Thayer School student handbook, which students receive during registration for their first term.

### **FOREIGN STUDY**

Credits earned at several institutions can be transferred toward either the A.B. or B.E. degree. Information about foreign study is at:  
[engineering.dartmouth.edu/academics/undergraduate/ab/foreign-study/](http://engineering.dartmouth.edu/academics/undergraduate/ab/foreign-study/)



# Bachelor of Arts (A.B.)

[engineering.dartmouth.edu/academics/undergraduate/ab/](http://engineering.dartmouth.edu/academics/undergraduate/ab/)

All A.B. engineering sciences programs are part of the liberal arts degree awarded by Dartmouth College.

Liberal arts courses including writing, first-year seminar, foreign languages, humanities, social science, world culture	10-14
Mathematics and science prerequisites including calculus and physics	7
Engineering sciences courses for the major or modified major	6-10
Free electives including additional liberal arts or engineering sciences courses	4-8
<b>Total courses</b>	<b>35</b>

Details of A.B. requirements can be found in the ORC/Catalog on Dartmouth's office of the Registrar website:  
[dartmouth.edu/~reg/](http://dartmouth.edu/~reg/)

## A.B. ENGINEERING SCIENCES PROGRAMS

DEGREE PROGRAM	BASIC MAJOR REQUIREMENTS	TOTAL	SEE PAGE
<b>Engineering Sciences major</b>	9-10 engineering sciences courses, including a culminating experience	9-10	20
<b>Biomedical Engineering Sciences major</b>	5 engineering sciences courses	11	21
	4 biology and chemistry courses		
	1 biochemistry or engineering sciences elective		
	Culminating experience in either engineering sciences or biochemistry		
<b>Engineering Physics major</b>	5 engineering sciences courses	10	22
	5 physics courses		
	Culminating experience in EITHER engineering sciences OR physics		
<b>Engineering Sciences major modified by another discipline</b>	6-7 courses in engineering sciences including a culminating experience	10-11	23-32
	4 courses in the other discipline		
<b>Engineering Sciences minor</b>	5 courses in math and physics plus 5 courses in engineering sciences	10	33
<b>Human-Centered Design minor</b>	2 engineering sciences courses	6	34
	4 courses in other discipline		
<b>Materials Science minor</b>	4 materials science courses	10	35
	6 courses in chemistry, physics, OR engineering sciences		
<b>Major modified by Engineering Sciences</b>	3-4 courses in math and physics plus 4 courses in engineering sciences	7-8	36

Culminating Experience

Engineering Sciences majors, modified majors, and Engineering Physics majors complete a culminating experience, which is part of a course (either as one of the two electives or as an additional course). Normally taken during the senior year, the course is chosen from the following:

Thesis	ENGS 86 Independent Project OR ENGS 88 Honors Thesis
Design project	ENGS 89* Engineering Design Methodology and Project Initiation (taken as part of the two-course design sequence ENGS 89/90). May count toward both A.B. and B.E. degrees.
Advanced course	<div>An advanced engineering sciences course with a significant design or research project chosen from an approved list available from the chair of the Engineering Sciences Department or at <a href="http://engineering.dartmouth.edu/academics/undergraduate/ab/major/">engineering.dartmouth.edu/academics/undergraduate/ab/major/</a></div> <div>Biomedical Engineering Sciences majors should choose from ENGS 160, 161, 162, 163, 165, 167 or 169.</div> <div>Engineering Physics majors may also choose from PHYS 68, 72, 73, 74, 76, 82, 87</div>

\* Prior to enrollment in ENGS 89, at least 6 engineering sciences courses must be completed: ENGS 21 plus 5 additional courses numbered 22 to 76.

## ENGINEERING AS A FOUNDATION FOR PROFESSIONAL FIELDS

A major in engineering sciences serves as an entry into any field where problem solving, analytical thinking and inventiveness are important. For students interested in specific professional fields, the following majors, minors, and modified majors are possible:

PROFESSIONAL FIELD	MAJOR	SEE PAGE
Architecture	Engineering Sciences major modified with Studio Art	32
Biomedical engineering	Biomedical Engineering Sciences major	21
Biotechnology	Engineering Sciences major modified with Biology	23
Chemical engineering	Engineering Sciences major modified with Chemistry	24
Computer engineering	Engineering Sciences major modified with Computer Science	25
Environmental engineering	Engineering Sciences major modified with Environmental Sciences	28
Any engineering field or interdisciplinary engineering	Engineering Sciences major	20
Engineering physics	Engineering Physics major	22
Geology	Engineering Sciences major modified with Earth Sciences	26
Human-centered design	Human-Centered Design minor	34
Management and financial engineering	Engineering Sciences major modified with Economics	27
Materials science	Materials Science minor with Chemistry or Physics major	35
Medicine	Biomedical Engineering Sciences major	21
Neuroscience	Engineering Sciences major modified with Neuroscience	29
Product design	Engineering Sciences major modified with Studio Art	32
Technology in public policy	Engineering Sciences modified with Public Policy	30

Students interested in professional fields other than those listed above can create modified majors tailored to their interests. A coherent program of study with substantial engineering content should be developed in consultation with the chair of the engineering department, Professor Erland Schulson, and filed with the registrar.

ENGINEERING SCIENCES MAJOR

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus		3 courses
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 11 Multivariable Calculus for Two-Term Advanced Placement First-Year Students OR		
	MATH 13 Calculus of Vector-Valued Functions		
Physics	PHYS 13, 14 Introductory Physics I, II		2 courses
Chemistry	CHEM 5 General Chemistry		1 course
Computer Science (choose 1 option)	ENGS 20 Introduction to Scientific Computing*		1-2 courses
	COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming		
REQUIRED COURSES			
Common core courses	ENGS 21 Introduction to Engineering		3 courses
	ENGS 22 Systems		
	ENGS 23 Distributed Systems and Fields		
Distributive core courses (choose 2)	ENGS 24 Science of Materials		2 courses
	ENGS 25 Introduction to Thermodynamics		
	ENGS 26 Control Theory		
	ENGS 27 Discrete and Probabilistic Systems		
Gateway courses (choose 2, each from a different discipline)	Electrical	ENGS 31 Digital Electronics	2 courses
		ENGS 32 Electronics: Introduction to Linear and Digital Circuits	
	Mechanical	ENGS 33 Solid Mechanics	
		ENGS 34 Fluid Dynamics	
	Chemical/biochemical	ENGS 35 Biotechnology and Biochemical Engineering	
		ENGS 36 Chemical Engineering	
Environmental	ENGS 37 Introduction to Environmental Engineering		
Electives (choose 2, either both from the engineering sciences option or one from each option)	Engineering sciences option	Any engineering sciences (ENGS) course above ENGS 20 (excluding ENGS 80 and 87)	2 courses
	Science/math option	ASTR 15 and above; BIOL 12 and above (except 52); CHEM 6, 10 and above (except 63); EARS 31, 33, 35, 37, 40-52, 59, 62, 64, 66-75, 79 and above; ENVS 30 and 79; MATH 17 – 29, 31, 32, 35, 38, 39, 40, 42, 43, 50 and above; PHYS 19 or 24, 41 and above (except 48); COSC 30, 31, 39, 49, 71, 74	
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For advice, contact the chair of Engineering Sciences, Professor Erland Schulson.

\* May not be taken under the Non-Recording Option (NRO).

## BIOMEDICAL ENGINEERING SCIENCES MAJOR

The biomedical engineering sciences major is offered to students interested in medical school. Faculty from Thayer School and Geisel School of Medicine jointly advise the research projects. Geisel School of Medicine offers an opportunity for accomplished biomedical engineering sciences majors to apply for early admission to the Geisel School of Medicine through the Early Assurance Program. For more information, please consult the Thayer website at:

[engineering.dartmouth.edu/academics/undergraduate/ab/biomed-major/](http://engineering.dartmouth.edu/academics/undergraduate/ab/biomed-major/)

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus		3 courses
	MATH 8 Calculus of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions OR MATH 11 Multivariable Calculus for Two-Term Advanced Placement First-Year Students		
Chemistry	CHEM 5–6 General Chemistry OR CHEM 10 Honors First-Year Chemistry		1–2 courses
Physics	PHYS 13, 14 Introductory Physics I, II		2 courses
Computer Science (choose 1 option)	ENGs 20 Introduction to Scientific Computing*		1-2 courses
	COSc 1 Introduction to Programming and Computation AND COSc 10 Problem Solving via Object-Oriented Programming		
REQUIRED COURSES			
Common core courses	ENGs 21 Introduction to Engineering		2 courses
	ENGs 22 Systems		
Common and distributive core courses (choose 1)	ENGs 23 Distributed Systems and Fields		1 course
	ENGs 24 Science of Materials		
	ENGs 25 Introduction to Thermodynamics		
	ENGs 26 Control Theory		
	ENGs 27 Discrete and Probabilistic Systems		
Gateway course (choose 1)	Electrical	ENGs 31 Digital Electronics	1 course
		ENGs 32 Electronics: Introduction to Linear and Digital Circuits	
	Mechanical	ENGs 33 Solid Mechanics	
		ENGs 34 Fluid Dynamics	
	Chemical/ biochemical	ENGs 35 Biotechnology and Biochemical Engineering	
		ENGs 36 Chemical Engineering	
Engineering course (choose 1)	ENGs 56 Biomedical Engineering OR 1 additional course from ENGs 23–36		1 course
Biology courses (choose 2)	BIOL 12 Cell Structure and Function		2 courses
	BIOL 13 Gene Expression and Inheritance		
	BIOL 30 (formerly 14) Physiology		
Chemistry courses	CHEM 51–52 Organic Chemistry OR CHEM 57–58 Organic Chemistry		2 courses
Elective** (choose 1)	Engineering Sciences course numbered above ENGs 23		1 course
	BIOL 40 (formerly 77) Biochemistry		
	CHEM 41 Biological Chemistry		
Culminating experience	Thesis or advanced course (see page 18)		1 course

For advice, contact Professor Brian Pogue.

\* May not be taken under the Non-Recording Option (NRO).

\*\* Students wishing to pursue the B.E. degree are advised to choose an Engineering Sciences course as their elective.

ENGINEERING PHYSICS MAJOR

The departments of Engineering Sciences and Physics and Astronomy offer the major in Engineering Physics.

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus	4 courses	
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions		
	MATH 23 Differential Equations		
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses	
Chemistry	CHEM 5 General Chemistry	1 course	
Computer Science (choose 1 option)	ENGS 20 Introduction to Scientific Computing*	1-2 courses	
	COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming		
REQUIRED COURSES			
Engineering core courses	ENGS 22 Systems	3 courses	
	ENGS 23 Distributed Systems and Fields		
	ENGS 24 Science of Materials		
Physics core courses**	PHYS 19 Introductory Physics III	3 courses	
	PHYS 24 Quantum Physics of Matter: An Introduction		
	PHYS 43 Statistical Physics		
Electives*** (choose 2, each from a different group)	Group 1	ENGS 25 Introduction to Thermodynamics	2 courses
		ENGS 33 Solid Mechanics	
		ENGS 34 Fluid Dynamics	
	Group 2	PHYS 42 Introductory Quantum Mechanics	
		PHYS 68 Introductory Plasma Physics	
		PHYS 91 Intermediate Quantum Mechanics	
	Group 3	PHYS 73 Introductory Condensed Matter Physics	
		ENGS 131 Science of Solid State Materials	
	Group 4	PHYS 66 Relativistic Electrodynamics	
		ENGS 120 Electromagnetic Fields and Waves	
	Group 5	PHYS 44 Mechanics	
		ENGS 72 Applied Mechanics: Dynamics	
Free electives*** (choose 2)	Any Engineering Sciences courses numbered above 20 (excluding ENGS 80 and 87) OR any physics course that fulfills the straight physics major		2 courses
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For advice, contact Professor William Lotko.

\* May not be taken under the Non-Recording Option (NRO).

\*\* Students taking the honors sequence, PHYS 15 and 16, should substitute a third physics elective for PHYS 19.

\*\*\* The Engineering Physics Major must be a 5/5 split of 10 courses between Engineering Sciences and Physics. These courses include the required 3 core courses and 2 electives or free electives in engineering and 2 electives or free electives in physics. Students wishing to pursue the B.E. degree are advised to elect an Engineering Sciences course.

## ENGINEERING SCIENCES MODIFIED WITH BIOLOGY

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13, 14 Introduction to Physics I, II	2 courses
Chemistry (choose 1)	CHEM 5 General Chemistry	1 course
	CHEM 10 Honors First-Year General Chemistry	
Computer Science	ENGS 20 Introduction to Scientific Computing*	1 course
Biology	BIOL 11 The Science of Life	2 courses
	BIOL 12 Cell Structure and Function	
REQUIRED COURSES		
Engineering core courses	ENGS 22 Systems	3 courses
	ENGS 25 Introduction to Thermodynamics	
	ENGS 35 Biotechnology and Biochemical Engineering	
Engineering electives (choose 3)	ENGS 21 Introduction to Engineering	3 courses
	ENGS 23 Distributed Systems and Fields	
	ENGS 24 Science of Materials	
	ENGS 26 Control Theory	
	ENGS 33 Solid Mechanics	
	ENGS 34 Fluid Dynamics	
	ENGS 36 Chemical Engineering	
	ENGS 37 Introduction to Environmental Engineering	
	ENGS 52 Introduction to Operations Research	
	ENGS 56 Introduction to Biomedical Engineering	
	ENGS 91 Numerical Methods in Computation	
	ENGS 161 Microbial Physiology and Metabolic Engineering (pending approval)	
	ENGS 165 Biomaterials	
Biology core course	BIOL 13 Gene Expression and Inheritance	1 course
Biology or chemistry electives (choose 3)	BIOL 34 Neurobiology	3 courses
	BIOL 35 Human Physiology	
	BIOL 37 Endocrinology	
	BIOL 42 Biology of the Immune Response	
	BIOL 43 Developmental Biology	
	BIOL 45 Molecular Biology	
	BIOL 46 Microbiology	
	BIOL 71 Current Topics in Cell Biology	
	CHEM 51 Organic Chemistry OR CHEM 57 Honors Organic Chemistry	
Culminating experience	Thesis, design project, or advanced course (see page 18)	

For advice, contact Professor Lee Lynd.

\* May not be taken under the Non-Recording Option (NRO).



ENGINEERING SCIENCES MAJOR MODIFIED WITH CHEMISTRY

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses
Chemistry	CHEM 5-6 General Chemistry OR CHEM 10 Honors First-Year General Chemistry	1-2 courses
Computer Science	ENGS 20 Introduction to Scientific Computing*	1 course
REQUIRED COURSES		
Engineering core courses	ENGS 22 Systems	3 courses
	ENGS 25 Introduction to Thermodynamics	
	ENGS 36 Chemical Engineering	
Engineering electives (choose 3 with not more than 2 from 21, 35, and 37 counting toward the major)	ENGS 21 Introduction to Engineering	3 courses
	ENGS 23 Distributed Systems and Fields	
	ENGS 24 Science of Materials	
	ENGS 26 Control Theory	
	ENGS 33 Solid Mechanics	
	ENGS 34 Fluid Dynamics	
	ENGS 35 Biotechnology and Biochemical Engineering	
	ENGS 37 Introduction to Environmental Engineering	
	ENGS 52 Introduction to Operations Research	
	ENGS 91 Numerical Methods in Computation	
Chemistry core courses	CHEM 51 Organic Chemistry OR CHEM 57 Honors Organic Chemistry	2 courses
	CHEM 75 Physical Chemistry I	
Chemistry electives (choose 2)	CHEM 41 Biological Chemistry I	2 courses
	CHEM 52 Organic Chemistry OR 58 Honors Organic Chemistry	
	CHEM 63 Environmental Chemistry	
	CHEM 64 Basic Inorganic Chemistry	
	CHEM 67 Physical Biochemistry I	
	CHEM 76 Physical Chemistry II	
Culminating experience	Thesis, design project, or advanced course (see page 18)	

For advice, contact Professor Lee Lynd.

\* May not be taken under the Non-Recording Option (NRO).

## ENGINEERING SCIENCES MAJOR MODIFIED WITH COMPUTER SCIENCE

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus		3 courses
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions		
Physics	PHYS 13, 14 Introductory Physics I, II		2 courses
Chemistry	CHEM 5 General Chemistry		1 course
Computer Science	COSC 1 Introduction to Programming and Computation		3 courses
	COSC 8 Problem Solving with Computer Science		
	COSC 10 Problem Solving via Object-Oriented Programming		
REQUIRED COURSES			
Engineering core courses (all of Group 1; choose 1 from Group 2)	Group 1	ENGS 22 Systems	4 courses
		ENGS 27 Discrete and Probabilistic Systems	
		ENGS 31 Digital Electronics	
	Group 2	ENGS 23 Distributed Systems and Fields	
		ENGS 24 Science of Materials	
Computer Science course	COSC 50 Software Design and Implementation		1 course
Breadth requirements (choose 5 including at least 1 from each group and 3 in Computer Science)	Group 1	ENGS 32 Electronics: Introduction to Linear and Digital Circuits	5 courses
		ENGS 62 Microprocessors in Engineered Systems	
		COSC 51 Computer Architecture	
	Group 2	ENGS 26 Control Theory	
		ENGS 68 Introduction to Communications Systems	
		ENGS 92 Fourier Transforms and Complex Variables	
		COSC 60 Computer Networks	
	Group 3	ENGS 91 Numerical Methods in Computation	
		COSC 31 Algorithms	
		COSC 58 Operating Systems	
		COSC 77 Computer Graphics	
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For advice, contact Professor Eugene Santos or Professor Steve Taylor.

ENGINEERING SCIENCES MAJOR MODIFIED WITH EARTH SCIENCES

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses
Chemistry	CHEM 5 General Chemistry	1 course
Computer Science	ENGS 20 Introduction to Scientific Computing*	1 course
Earth Sciences	1 introductory Earth Sciences course from EARS 1–9, exclusive of EARS 7	2 courses
	EARS 40 Materials of the Earth	
REQUIRED COURSES		
Engineering Sciences	ENGS 22 Systems	6 courses
	ENGS 23 Distributed Systems and Fields	
	ENGS 24 Science of Materials	
	ENGS 25 Introduction to Thermodynamics	
	2 Engineering Sciences electives	
Earth Sciences	4 Earth Sciences courses numbered above 10	4 courses
Culminating Experience	Thesis, design project, or advanced course (see page 18)	

For advice, contact Professor Erland Schulson.

\* May not be taken under the Non-Recording Option (NRO).

**ENGINEERING SCIENCES MAJOR MODIFIED WITH ECONOMICS**

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus		3 courses
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions		
Physics	PHYS 13, 14 Introductory Physics I, II		2 courses
Chemistry	CHEM 5 General Chemistry		1 course
Computer Science (choose 1 option)	ENGS 20 Introduction to Scientific Computing*		1-2 courses
	COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming		
Economics	ECON 1 The Price System: Analysis, Problems, and Policies		2 courses
	ECON 10 Introduction to Statistical Methods		
REQUIRED COURSES			
Engineering core courses	ENGS 21 Introduction to Engineering		3 courses
	ENGS 22 Systems		
	ENGS 52 Introduction to Operations Research		
Engineering electives (choose 1 from Group 1; 2 from Group 2)	Group 1	ENGS 23 Distributed Systems and Fields	3 courses
		ENGS 24 Science of Materials	
		ENGS 25 Introduction to Thermodynamics	
		ENGS 33 Solid Mechanics	
	Group 2	Any other Engineering Sciences course that counts toward the A.B.	
Economics courses (choose 2)	ECON 20 Econometrics		2 courses
	ECON 21 Microeconomics		
	ECON 22 Macroeconomics		
Economics electives (choose a 2-course sequence from a single group)	Money and Finance	ECON 26 The Economics of Financial Intermediaries and Markets	2 courses
		ECON 36 Theory of Finance	
	Industrial Organization	ECON 25 Industrial Organization and Public Policy	
		ECON 35 Games and Economic Behavior OR ECON 45 Topics in Industrial Organization	
	International Trade	ECON 29 International Finance and Open-Economy Macroeconomics	
		ECON 39 International Trade	
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For information, contact Professor Mark Borsuk.

\* May not be taken under the Non-Recording Option (NRO).

ENGINEERING SCIENCES MAJOR MODIFIED WITH ENVIRONMENTAL SCIENCES

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus	3 courses	
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions		
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses	
Chemistry (choose 1)	CHEM 5 General Chemistry	1 course	
	CHEM 10 Honors First-Year General Chemistry		
Computer Science	ENGS 20 Introduction to Scientific Computing*	1 course	
Biology	BIOL 16 Ecology**	1 course	
REQUIRED COURSES			
Engineering core courses	ENGS 22 Systems	3 courses	
	ENGS 25 Introduction to Thermodynamics		
	ENGS 37 Introduction to Environmental Engineering		
Engineering electives (choose 3, of which at least 2 must be from the subgroup 41, 43, 44)	ENGS 27 Discrete and Probabilistic Systems	3 courses	
	ENGS 34 Fluid Dynamics		
	ENGS 35 Biotechnology and Biochemical Engineering		
	ENGS 36 Chemical Engineering		
	ENGS 41 Sustainability and Natural Resource Management		
	ENGS 43 Environmental Transport and Fate		
	ENGS 44 Sustainable Design		
	ENGS 52 Introduction to Operations Research		
	ENGS 171 Industrial Ecology		
Environmental Sciences courses (choose 4, including at least 2 from a single department)	Biology	BIOL 21 Population Ecology OR BIOL 51 Advanced Population Ecology (but not both)	4 courses
		BIOL 22 Methods in Ecology	
		BIOL 25 Introductory Marine Biology and Ecology	
		BIOL 53 Aquatic Ecology	
	Chemistry	CHEM 51 Organic Chemistry (only as pre-requisite to CHEM 63)	
		CHEM 63 Environmental Chemistry	
	Earth Sciences	EARS 16 Hydrology and Water Resources	
		EARS 35 The Soil Resource	
		EARS 65 Remote Sensing	
		EARS 71 River Processes and Watershed Science	
		EARS 66 Contaminant Hydrogeology	
		EARS 76 Advanced Hydrology	
	Environmental Studies	ENVS 12 Energy and the Environment	
		ENVS 20 Conservation of Biodiversity	
		ENVS 25 Ecological Agriculture	
		ENVS 53 Science for Sustainable Systems	
		ENVS 55 Ecological Economics	
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For advice, contact Professor Benoit Cushman-Roisin or Professor Lee Lynd.

\* May not be taken under the Non-Recording Option (NRO).

\*\* BIOL 11 not needed as a prerequisite to BIOL 16 if ENVS 2, ENGS 37 or 41 have been taken.

## ENGINEERING SCIENCES MODIFIED WITH NEUROSCIENCE

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses
Chemistry	CHEM 5 General Chemistry	1 course
Computer Science (choose 1 option)	ENGs 20 Introduction to Scientific Computing*	1-2 courses
	COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming	
Neuroscience	PSYC 6 Introduction to Neurosciences	1 course
REQUIRED COURSES		
Engineering core courses	ENGs 21 Introduction to Engineering	4 courses
	ENGs 22 Systems	
	ENGs 26 Control Theory OR ENGs 27 Discrete and Probabilistic Systems	
	ENGs 31 Digital Electronics OR ENGs 32 Electronics: Introduction to Linear and Digital Circuits	
Engineering electives (choose 2)	ENGs 26 Control Theory (if not taken above)	2 courses
	ENGs 27 Discrete and Probabilistic Systems (if not taken above)	
	ENGs 30 Biological Physics	
	ENGs 31 Digital Electronics (if not taken above)	
	ENGs 32 Electronics: Introduction to Linear and Digital Circuits (if not taken above)	
	ENGs 33 Solid Mechanics	
	ENGs 56 Introduction to Biomedical Engineering	
	ENGs 57 Intermediate Biomedical Engineering	
	ENGs 61 Intermediate Electrical Circuits	
	ENGs 62 Microprocessors in Engineered Systems	
	ENGs 65 Engineering Software Design	
	ENGs 67 Programming Parallel Systems	
	ENGs 93 Statistical Methods in Engineering	
Neuroscience core courses (choose 2)	PSYC 45 Behavioral Neuroscience	2 courses
	PSYC 46 Cellular and Molecular Neuroscience	
	PSYC 65 Systems Neuroscience (formerly Physiology of Behavior)	
Neuroscience electives (choose 2)	PSYC 21 Perception	2 courses
	PSYC 27 Cognitive Neuroscience	
	PSYC 40 Introduction to Computational Neuroscience	
	PSYC 60 Principles of Human Brain Mapping with fMRI	
	BIOL 27 Animal Behavior	
	PSYC 64 Sensory Psychology	
	PSYC 8X Seminars in Neuroscience (allow one seminar only as one of the two electives)	
Culminating experience	Thesis, design project, or advanced course (see page 18)	

For advice, contact Professor Laura Ray.

\* May not be taken under the Non-Recording Option (NRO).

ENGINEERING SCIENCES MAJOR MODIFIED WITH PUBLIC POLICY

PREREQUISITES			
Mathematics	MATH 3 Introduction to Calculus	3 courses	
	MATH 8 Calculus of Functions of One and Several Variables		
	MATH 13 Calculus of Vector-Valued Functions		
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses	
Chemistry	CHEM 5 General Chemistry	1 course	
Computer Science (choose 1 option)	ENGS 20 Introduction to Scientific Computing*	1-2 courses	
	COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming		
Statistical data analysis (choose 1)	ECON 10 Introduction to Statistical Methods	1 course	
	SOCY 10 Quantitative Analysis of Social Data		
	MATH 10 Introductory Statistics		
REQUIRED COURSES			
Engineering core courses	ENGS 21 Introduction to Engineering	2 courses	
	ENGS 22 Systems		
Engineering electives (choose 1 from each group)	Group 1	ENGS 23 Distributed Systems and Fields	4 courses
		ENGS 24 Science of Materials	
		ENGS 25 Introduction to Thermodynamics	
		ENGS 26 Control Theory	
		ENGS 27 Discrete and Probabilistic Systems	
	Group 2	ENGS 31 Digital Electronics	
		ENGS 32 Electronics: Introduction to Linear and Digital Circuits	
		ENGS 33 Solid Mechanics	
		ENGS 34 Fluid Dynamics	
		ENGS 35 Biotechnology and Biochemical Engineering	
		ENGS 36 Chemical Engineering	
		ENGS 37 Introduction to Environmental Engineering	
	Group 3	ENGS 41 Sustainability and Natural Resources Management	
		ENGS 43 Environmental Transport and Fate	
		ENGS 44 Sustainable Design	
		ENGS 52 Introduction to Operations Research	
		ENGS 56 Introduction to Biomedical Engineering	
	Group 4	Any ENGS course numbered above 20 (excluding ENGS 80 and 87)	

continued



**ENGINEERING SCIENCES MAJOR MODIFIED WITH PUBLIC POLICY cont.**

REQUIRED COURSES			
Public Policy (choose 4 with at least 1 from each group)	Group 1	PBPL 5 Introduction to Public Policy	4 courses
	Group 2	PBPL 40 Economics of Public Policymaking	
		PBPL 41 Writing and Speaking Public Policy	
		PBPL 42 Ethics and Public Policy	
		PBPL 43 Social Entrepreneurship	
		PBPL 45 Introduction to Public Policy Research	
		PBPL 47 Foundations of Leadership	
		ECON 20 Econometrics	
	Group 3	Any course (excluding Engineering Sciences) from a policy track, such as Environment and Public Policy, Health and Public Policy, Natural Resources and Public Policy, Science/Technology and Public Policy	
Culminating experience	Thesis, design project, or advanced course (see page 18)		

For advice, contact Dean Joseph Helble. Information on Public Policy courses and tracks is at: [rockefeller.dartmouth.edu/minor/](http://rockefeller.dartmouth.edu/minor/)

\* May not be taken under the Non-Recording Option (NRO).

ENGINEERING SCIENCES MAJOR MODIFIED WITH STUDIO ART

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses
Chemistry	CHEM 5 General Chemistry	1 course
Computer Science	ENGS 20 Introduction to Scientific Computing*	1 course
REQUIRED COURSES		
Engineering core courses	ENGS 21 Introduction to Engineering	4 courses
	ENGS 22 Systems	
	ENGS 24 Science of Materials	
	ENGS 33 Solid Mechanics	
Engineering electives	Any 2 engineering sciences courses available for A.B. credit in the major.	2 courses
Studio Art core courses	SART 15 Drawing I	2 courses
	SART 16 Sculpture I	
Studio Art electives	Any upper level Studio Art course	2 courses
Culminating experience	Thesis, design project, or advanced course (see page 18)	

For advice, contact Professor Peter Robbie.

\* May not be taken under the Non-Recording Option (NRO).

## ENGINEERING SCIENCES MINOR

Students should note that many Engineering Sciences courses require prerequisites in addition to those noted. No courses other than those used as prerequisites to the minor may be taken under the Non-Recording Option to satisfy requirements of the minor.

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	3 courses
	MATH 8 Calculus of Functions of One and Several Variables	
	MATH 13 Calculus of Vector-Valued Functions	
Physics	PHYS 13 Introductory Physics I	2 courses
	PHYS 14 Introductory Physics II	
REQUIRED COURSES		
Core courses	ENGS 20 Introduction to Scientific Computing, OR COSC 1 Introduction to Programming and Computation AND COSC 10 Problem Solving via Object-Oriented Programming	3 courses
	ENGS 21 Introduction to Engineering	
	ENGS 22 Systems	
Electives (choose 2)	Any engineering sciences undergraduate course numbered above 20 (excluding 80 and 87)	2 courses

For advice, contact the chair of Engineering Sciences, Professor Erland Schulson.

HUMAN-CENTERED DESIGN MINOR

The minor in Human-Centered Design is an interdisciplinary program focused on the process of innovation for addressing human needs.

PREREQUISITES		
Design Foundation	ENGS 12 Design Thinking	2 courses
	ENGS 21 Introduction to Engineering	
REQUIRED COURSES		
Ethnographic Methods and Human Factors (Psychology)	ANTH 3 Intro to Cultural Anthropology	2 courses
	ANTH 18 Intro to Research Methods in Cultural Anthropology	
	ANTH 56 Intro to Research Methods in Medical Anthropology	
	SOCY 11 Research Methods	
	GEOG 11 Qualitative Methods and the Research Process in Geography	
	PSYC 21 Perception	
	PSYC 22 Learning	
	PSYC 23 Social Psychology	
	PSYC 27 Cognitive Neuroscience	
	PSYC 28 Cognition	
	PSYC 40 Intro to Computational Neuroscience	
	PSYC 43 Emotion	
Design Electives	ENGS 75 Product Design*	2 courses
	COSC 28 Advanced Projects in Digital Arts	
	FILM 51 Game Design	
	PBPL 43 Social Entrepreneurship	
	SART 65 Architecture I	
	SART 66 Architecture II	
	SART 68 Architecture III	
	Independent Study in a relevant discipline	

Students may petition the department to substitute relevant courses in section 2 (that cover ethnographic methodology or human factors psychology) and 3 (that focus on problem-solving of human needs and result in the creation of artifacts). Before taking courses in section 3, students must complete both courses in section 1 plus at least one course from section 2.

For advice contact Professor Peter Robbie (Engineering Sciences) or Professor Lorie Loeb (Computer Science).

\* For Engineering Majors: If ENGS 75 is selected for the minor, it may not be counted toward the major.

## MATERIALS SCIENCE MINOR

The departments of Chemistry, Physics, and Engineering Sciences offer the minor in Materials Science, which can be combined with majors in any of the three areas.

PREREQUISITES			
Chemistry	CHEM 5-6 General Chemistry	2 courses	
Physics	PHYS 13, 14 Introductory Physics I, II	2 courses	
REQUIRED COURSES			
Core course	ENG5 24 Science of Materials	1 course	
Required course (choose 1)	PHYS 76 Methods of Experimental Physics	1 course	
	ENG5 133 Methods of Materials Characterization		
Electives (choose 2, each from a different group)	Group 1	ENG5 131 Science of Solid State Materials	2 courses
		PHYS 73 Condensed Matter Physics I	
	Group 2	CHEM 108 Chemistry of Macromolecules: Physical Properties and Characterization	
		CHEM 109 Chemistry of Macromolecules: Synthesis and Characterization	
	Group 3	ENG5 73 Materials Processing and Selection	
		ENG5 132 Thermodynamics and Kinetics in Condensed Phases	
		PHYS 43 Statistical Physics	

Note: If ENGs 137 is taken as a general requirement, at least one elective must be taken from outside the Engineering Sciences department.

For advice, contact the chair of Engineering Sciences, Professor Erland Schulson.

OTHER MAJOR MODIFIED WITH ENGINEERING SCIENCES

Any major can be modified with Engineering Sciences. Students should note that many Engineering Sciences courses require prerequisites in addition to those noted. No electives may be taken under the Non-Recording Option.

PREREQUISITES		
Mathematics	MATH 3 Introduction to Calculus	2 courses
	MATH 8 Calculus of Functions of One and Several Variables	
Physics	PHYS 13 Introductory Physics I (or PHYS 3-4)*	1-2 courses
REQUIRED COURSES		
Core courses (choose 1)	ENGS 21 Introduction to Engineering	1 course
	ENGS 22 Systems	
Electives (choose 3)	Any engineering sciences course numbered above 20 (excluding 80 and 87)	3 courses

For advice, contact the chair of Engineering Sciences, Professor Erland Schulson, and the chair of the department of the major.

\* Must have been taken at Dartmouth. AP credit not permitted.

# Bachelor of Engineering (B.E.)

[engineering.dartmouth.edu/academics/undergraduate/be/](http://engineering.dartmouth.edu/academics/undergraduate/be/)

The Bachelor of Engineering (B.E.) program is a professional engineering program accredited by the Engineering Accreditation Commission of ABET, 111 Market Place, Suite 1050, Baltimore, MD 21202-4012, Telephone: (410) 347-7700.

## PROGRAM OBJECTIVES

B.E. program goals are to educate students within the context of Thayer School's educational philosophy and the accreditation requirements. Graduates of the B.E. program have the experience, skills, and knowledge to:

- apply mathematics, science, and engineering to identify and solve engineering problems
- design and conduct experiments, analyze and interpret data
- design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- function on multidisciplinary teams
- identify, formulate, and solve engineering problems
- exercise professional and ethical responsibility
- communicate effectively
- understand the impact of engineering solutions in a global, economic, environmental, and societal context
- recognize the need for and engage in life-long learning
- understand contemporary issues
- use the techniques, skills, and modern engineering tools necessary for engineering practice

Complete information about ABET criteria for the B.E. degree are at: [abet.org](http://abet.org)

## RESIDENCY

Completion of the B.E. program after the A.B. degree generally requires between one and 3 terms at Thayer School depending on courses taken during the first 4 years. Advanced standing on entry to Dartmouth may shorten the overall time required; some students complete both the A.B. and B.E. in 4 years.

## NUMBER OF COURSES

The B.E. degree requires a minimum of 9 courses beyond the requirements for the A.B. degree. At least 6 courses must have significant engineering design content.

B.E. REQUIREMENTS

B.E. students take required courses and electives in mathematics, basic science, engineering sciences, and engineering design. Students can plan their A.B. and B.E. degree programs using the following chart.

Mathematics and natural science	MATH 3, 8, 13	9 courses
	PHYS 13, 14	
	CHEM 5	
	ENGs 91, 92, or 93	
	2 non-introductory courses chosen from ASTR 15 and above; BIOL 12 and above (except 52); CHEM 6, 10 and above (except 63); EARS 31, 33, 35, 37, 40-52, 59, 62, 64, 66-76, 79 and above; ENVS 30 and 79; MATH 17-29, 31, 32, 35, 38, 39, 40, 42, 43, 50 and above; PHYS 19 or 24, 30/ENGs 30, 41 and above (except 48); COSC 30/ENGs 66, 31, 39, 49, 71, 74	
Engineering common core	ENGs 20 (counts as 0.5 course for B.E. credit)	3.5 courses
	ENGs 21, 22, 23	
Engineering distributive core (choose 2)	ENGs 24, 25, 26, 27	2 courses
Engineering gateway (choose 2 from 2 different disciplines)	ENGs 31 or 32, ENGs 33 or 34, ENGs 35 or 36, ENGs 37	2 courses
Engineering electives (choose 6)	3 courses must form a coherent disciplinary concentration* with 1 of these having significant design content; the remaining 3 electives may be chosen from ENGs or ENGG courses numbered 24-88 (except 30, 66, 75, 80, 87), 107-177, 192 and 199; COSC 50-84 (except 30, 31, 39, 49, 71, 74) and COSC 170-276 (except 174, 179, 189, 210). Two of the 3 electives may be mathematics or natural science courses as listed above.	6 courses
Capstone engineering design	ENGs 89/90 (Prior to enrollment in ENGs 89, at least 6 engineering courses must be completed. These include ENGs 21 plus 5 additional courses numbered 22 to 76.)	2 courses
Total		24.5 courses

Detailed information about specific courses that satisfy accreditation and Thayer School requirements is in the Bachelor of Engineering Program Plan, available at [dartmouth.edu/bannerstudent](http://dartmouth.edu/bannerstudent)

**NOTE:** The only B.E. courses that can be taken under the Non-Recording Option are MATH 3, 8, 13; PHYS 13, and CHEM 5.

\* With the exception of one of either ENGs 34 (prerequisites 20, 22, 23, 25) or ENGs 36 (prerequisites 20, 22, 25), courses to be included in the area of “three-course concentration” will be numbered above ENGs/ENGG 40 and will require at least one prerequisite either from the series ENGs 20-37 or from advanced courses within the sciences. With permissions, suitable advanced science courses may count within the three-course concentration. To include ENGs 86 or 88 in the three-course concentration, a proposal, which includes prerequisite courses, a syllabus, learning objectives and what principles of engineering will be mastered, needs to be submitted in advance (before the fourth week of the term prior to which ENGs 86 or 88 will be taken) and approved by the B.E. Committee.



## Dual-Degree Program

[engineering.dartmouth.edu/academics/undergraduate/dual/](http://engineering.dartmouth.edu/academics/undergraduate/dual/)

The dual-degree program provides an opportunity for students at other liberal arts colleges to take engineering courses at Dartmouth. Students spend their junior or senior year on exchange at Dartmouth, return to their home school for graduation, and then return to Dartmouth for a second year to complete the B.E. program.

## Sample A.B./B.E. Programs

[engineering.dartmouth.edu/academics/undergraduate/be/samples/](http://engineering.dartmouth.edu/academics/undergraduate/be/samples/)

Students interested in focusing their A.B./B.E. studies in a specific engineering discipline may review online sample programs in the following fields:

- Biochemical Engineering or Biotechnology
- Biomedical Engineering
- Chemical Engineering
- Computer Engineering
- Electrical Engineering
- Environmental Engineering
- Materials Science and Engineering
- Mechanical Engineering

## Undergraduate Admissions

### A.B. ADMISSIONS

Admission to the A.B. program is through the Dartmouth Admissions Office, McNutt Hall, Hanover, NH 03755.  
[www.dartmouth.edu/admissions/](http://www.dartmouth.edu/admissions/)

### B.E. ADMISSIONS

#### Admission Requirements

Dartmouth students finishing an A.B. degree with a major or modified major in Engineering Sciences are automatically admitted to the B.E. program.

Students with an accredited degree in engineering from other colleges and universities are eligible for admission.

Students with a bachelor's degree that is substantially equivalent to the Dartmouth A.B. in Engineering Sciences plus two upper-level electives in engineering, mathematics, or the natural sciences are also eligible for admission.

Students with minor deficiencies may be admitted but will be required to complete additional undergraduate course work.

Students who need more than one full term (3 courses) are required to enroll initially as special students.

**Special Students:** Students who do not meet requirements for admission to the B.E. program may be admitted as special students. Students who need no more than the equivalent of one term to satisfy prerequisites will be considered for admission as regular degree candidates.

**Part-Time Students:** Residents of the Upper Valley region who have a B.S. in engineering or an appropriate math/science program and can meet basic academic requirements may pursue coursework on a part-time basis.

### **Application Procedure**

Current Dartmouth students and dual-degree students can download an electronic copy of the application from:

[engineering.dartmouth.edu/academics/admissions/undergraduate/be/](http://engineering.dartmouth.edu/academics/admissions/undergraduate/be/)

Students from other colleges and universities can receive an application through the mail by emailing:

[engineering.admissions@dartmouth.edu](mailto:engineering.admissions@dartmouth.edu)

Prospective students from the U.S. and Canada can call toll-free:

1-888-THAYER6 [1-888-842-9376]

Prospective students from other parts of the world should call:

1-603-646-2606

Completed applications, with supporting documents, should be sent to:

Engineering Admissions

Thayer School of Engineering

Dartmouth College

14 Engineering Drive

Hanover, NH 03755-8000

**Application deadline:** 2 terms prior to the beginning term of the B.E. program.

The B.E. program plan is submitted to the B.E. Program Committee at the time of application.

## **Tuition and Expenses**

Tuition for the 2014–2015 academic year is \$15,588 per term, which covers instruction, use of instructional facilities, and health care service through the College infirmary.

Students without their own hospital coverage must purchase a Dartmouth College hospital insurance policy for approximately \$2,500 per year.

The total cost of a year in the B.E. program, including tuition, books, room, board, and incidentals, will be approximately \$63,000–65,000 for the academic year 2014–2015. Financial aid can significantly lower the yearly cost.

## **Financial Aid**

Full-time students in the B.E. program are eligible for aid in the form of partial-tuition scholarships, hourly employment as teaching assistants or in other capacities, fellowships, and loans. Special and part-time students are not eligible for financial aid.

The assessment of need is based on the PROFILE application at:

[profileonline.collegeboard.com](http://profileonline.collegeboard.com)

Awards are made annually on an academic year basis. Financial aid information is available at:

[engineering.dartmouth.edu/academics/admissions/financial-aid/](http://engineering.dartmouth.edu/academics/admissions/financial-aid/)

## HOURLY TEACHING ASSISTANTSHIPS AND OTHER EMPLOYMENT

Teaching assistants positions may be available to well qualified students. A teaching assistant is paid hourly to assist with grading, problem sessions, and/or lab work. Assignments are made on a term-by-term basis. Other limited hourly employment is also available to qualified students.

Hourly rates depend on the nature of the work and the student's ability. Normally work is limited to no more than 12 hours per week during academic terms and 40 hours per week between terms and during off-terms. Hourly employment may not exceed a total of 40 hours per week from any and all College sources.

## PARTIAL TUITION SCHOLARSHIPS

Grants applicable to tuition charges are awarded on the basis of need, as demonstrated by the PROFILE application. Scholarships are renewed each academic year contingent upon continued satisfactory academic progress.

## LOANS

B.E students are eligible to apply for federal Stafford Loans, federal Perkins Loans, and DELC Loans through the Dartmouth Financial Aid Office. Educational loan applicants must complete and submit a Free Application for Federal Student Aid (FAFSA) form. This form may be obtained at:  
fafsa.ed.gov

# Registration

## RESIDENCY

B.E. candidates enrolled in 2 or more courses are considered full-time students and as being in residence.

## CHECK-IN

All students intending to be in residence must check in at the beginning of each term (see Academic Calendar, page 2) through an on-line check-in process. This practice lets the faculty and administration know who is actually in residence for the new term and facilitates contacting students with individual problems.

A \$50 penalty will be charged for late check-in (10 days after check-in day).

A student who, for good reason, must check in late may petition the registrar for waiver of this charge.

All College financial accounts must be settled prior to check-in. A student who has failed to settle financial accounts will not be allowed to check in.

## COURSE CHANGES

Check-in has no direct connection with the changing of courses. Registered students may change courses through the Internet (using the student "Banner" home page) or at the Office of the Registrar. Each term, a 5-day period is available for adding, dropping, or exchanging courses; no approval is needed. If possible, students should arrange their course load during this period.

During the second 5 class days of a term a student may add or exchange courses by requesting an instructor override for the intended new courses.

## WITHDRAWAL

**Courses.** Until 2 weeks before the last class of the term, students may withdraw from a course at their own discretion. A student needing to withdraw must obtain the instructor's signature on a drop form and submit it to the registrar before the deadline indicated each term. The course remains on the student's transcript with the notation "W," for "withdrew."

**Degree Programs.** A student may withdraw (i.e., terminate residence) from degree candidacy at any time. If a student withdraws during the first 10 class days, the notation "withdrew for the term, in good standing" will be entered on the transcript. If withdrawal occurs after the first 10 class days, with certification by the instructor of each course that the student is in good standing, the notation "withdrew for the term, in good standing" will be entered on the transcript; otherwise, each course will be entered followed by the notation "withdrew."

Withdrawal for medical reasons, when verified by the student's physician, will be entered as such. Students who withdraw from degree candidacy and later wish to resume degree candidacy must petition the director of their degree program in writing for re-admission.

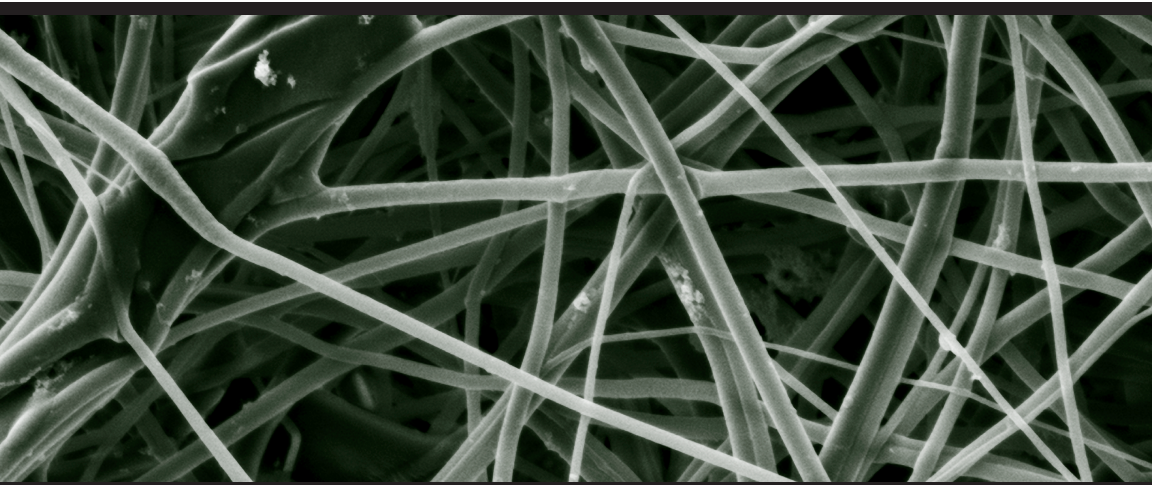
## REFUND POLICY

The Thayer School policy on refund of payments by students who withdraw voluntarily or are dismissed from the School during any term is as follows:

**Tuition.** A full refund is issued to students who withdraw or are dismissed before the beginning of term classes. During the first week, the refund is 90%; during the second and third weeks, 75%; during the fourth week, 50%; during the fifth week, 25%. After the fifth week, there is no refund.

Requests for refunds should be submitted in writing to the Controller of Dartmouth College, 6132 McNutt Hall, Room 103, Hanover, NH 03755, (603) 646-3230. Any balance due the student will be paid within 40 days.

# Graduate Studies



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# Graduate Studies

## Master of Engineering Management (M.E.M)

[engineering.dartmouth.edu/academics/graduate/mem/](http://engineering.dartmouth.edu/academics/graduate/mem/)

The Master of Engineering Management (M.E.M.) program is a professional degree program that combines engineering and management courses taught by faculty from Thayer School and Tuck School of Business. Graduates of the program are engineers who understand the business of technology.

### CURRICULUM

The curriculum integrates engineering, mathematics, and core management courses. Electives typically are engineering and management courses, but students may also choose courses from Dartmouth's other graduate science departments, Geisel School of Medicine, The Dartmouth Institute, or from Vermont Law School.

### ADVISORS

A faculty advisor helps each student develop a program of study. Each program form is submitted to and approved by the M.E.M. Director during the student's first term of residence and updated each term of progress through the Program.

### RESIDENCY

Students must be in residence for a minimum of 3 academic terms.

- Students who hold an ABET-accredited B.S. degree in engineering (or its equivalent) from a college other than Dartmouth generally require 4 terms plus the summer internship.
- Students who hold the Dartmouth A.B. in Engineering Sciences plus the Thayer School B.E. can finish the M.E.M. program in 3 terms.
- Students whose bachelor's degree is NOT an ABET-accredited B.S. degree in engineering (or its equivalent) may have to take additional coursework to complete the M.E.M. degree.

### NUMBER OF COURSES

The number of courses required depends on the student's preparation. Students entering the program from a college other than Dartmouth generally take 14 courses. Dartmouth students, including dual-degree students who have taken the B.E. at Thayer School, may count ENGS 93 Statistical Methods in Engineering toward the M.E.M. degree, even if it is taken as part of the A.B. and/or B.E. requirements. Typically a holder of the Thayer School B.E. degree can complete the M.E.M. degree with 13 courses beyond the B.E. degree. With the exception of ENGM 387, four-course loads, for courses to be used in satisfaction of the M.E.M. requirements, must be pre-approved by the M.E.M. Director.

### INTERNSHIPS

Students participate in an industry internship for ENGG 390 Master of Engineering Management Project/Internship, usually in the summer term. Students register for ENGG 390 in the term in which the work is done. A course fee applies.

## GRADE STANDARDS

The grade assigned at the completion of any graduate-level course is one of the following:

GRADE	EQUIVALENT	INDICATES
HP (High Pass)	A, A-	Distinctly superior work
P (Pass)	B+, B, B-	Good work
LP (Low Pass)	C+, C, C-	Work deficient but acceptable for graduate credit
CR (Credit)	Passing	Satisfactory work (in courses, where HP, P, or LP grade assignment is inappropriate; not intended as alternative to HP, P, or LP)
NC (No Credit)	D, E	Unsatisfactory work, not acceptable for graduate credit

No more than one LP grade for every 6 courses may be submitted in satisfaction of M.E.M. degree requirements. Any student who earns LP or lower in courses that satisfy degree requirements receives a letter of warning from the director of his or her graduate program. A detailed statement on the Student Probation Policy is available from the registrar.

## ACADEMIC HONOR

All students, upon matriculation, sign a statement that they agree to abide by the honor principles and Student Conduct Code established by Dartmouth College. A full statement appears in the student handbook, which students receive during registration.

## INDUSTRY PARTNERS

M.E.M. students have several opportunities to work with practicing engineers and engineering managers. In the first fall term technology assessment course (ENGM 178), student teams are paired (when possible) with industry partners to develop a thorough assessment of an assigned technology topic area. Each team works with faculty and (when appropriate) an industry partner to develop the assessment report. Over the 12 weeks between assignment definition and final deliverable, the student teams present their on-going work to professional managers and engineers on review boards.

The ENGG 390 Master of Engineering Management Project/Internship is tied to an internship at an industry sponsor's company. The internship may focus on engineering or management or both, with students presenting their results to a professional review board.

M.E.M. COURSE REQUIREMENTS

Professional Skills	ENGM 387 M.E.M. Professional Skills	1 course
Applied mathematics	ENGs 93 Statistical Methods in Engineering	2 courses
	ENGM 184 Introduction to Optimization Methods	
Engineering project/design sequence	ENGM 178 Technology Assessment	2 courses
	ENGG 390 M.E.M. Project/Internship	
Engineering and engineering management required courses	ENGG 177 Decision-Making Under Risk and Uncertainty	5 courses
	ENGM 179 Accounting	
	ENGM 180 Corporate Finance	
	ENGM 181 Marketing	
	ENGM 183 Operations Management	
Engineering management electives (choose 1)	ENGs 157 Chemical Process Design	1 course
	ENGs 171 Industrial Ecology	
	ENGM 185 Topics in Manufacturing Design and Processes	
	ENGM 186 Technology Project Management	
	ENGM 188 Law, Technology and Entrepreneurship	
	ENGM 189 Medical Device Development (.5 credit)	
M.E.M. free electives (choose 3)	Any graduate engineering sciences or engineering course	3 courses
	Business and management courses from Tuck School*	
	Graduate courses from Dartmouth science departments	
	Courses from Geisel School of Medicine	
	Environmental law courses from Vermont Law School	
TOTAL		14 courses

\* M.E.M. tuition covers 2 courses from Tuck School; extra tuition will be charged for a third Tuck course.

Typical Course Sequence—M.E.M. Only

The following is the typical program for a student with an ABET-accredited B.S. degree in engineering or its equivalent from a school other than Dartmouth. Students who do not hold an accredited degree may be required to take additional courses.

Fall	ENGM 178 Technology Assessment
	ENGM 181 Marketing
	ENGM 184 Introduction to Optimization Methods
	ENGM 387 M.E.M. Professional Skills
Winter	ENGs 93 Statistical Methods in Engineering
	ENGM 179 Accounting
	M.E.M. free elective
Spring	ENGM 180 Corporate Finance
	ENGM 183 Operations Management
	M.E.M. free elective
Summer	ENGG 390 M.E.M. Project/Internship (Typically the project is accomplished within the context of an industry internship with the final presentation given in the fall term.)
Fall	ENGG 177 Decision-Making under Risk and Uncertainty
	Engineering management elective
	M.E.M. free elective



### Typical Course Sequence—Combined B.E./M.E.M.

Dartmouth A.B. graduates who majored in Engineering Sciences will normally complete the B.E. degree before completing the M.E.M. degree. Since ENGS 93 from either the A.B. or B.E. degree programs may be counted toward the M.E.M. degree, Dartmouth students typically complete the M.E.M. degree with 13 courses beyond the B.E. degree. During the A.B. years, students should take two engineering sciences electives beyond what is required for the major.

A.B. YEARS	
	2 engineering sciences electives beyond what is required for the major
B.E. YEAR	
Fall	ENGS 89 Engineering Design Methodology and Project Initiation (B.E. requirement)
	ENGM 178 Technology Assessment
	ENGM 387 M.E.M. Professional Skills
	Engineering sciences elective
Winter	ENGS 90 Engineering Design Methodology and Project Completion (B.E. requirement)
	ENGS 93 Statistical Methods in Engineering
	Engineering sciences elective
Spring	Two engineering sciences electives
	One engineering management elective
M.E.M. YEAR	
Summer	ENGG 390 M.E.M. Project/Internship (Typically the project is accomplished within the context of an industry internship with the final presentation given in the fall term.)
Fall	ENGG 177 Decision-Making under Risk and Uncertainty
	ENGM 181 Marketing
	ENGM 184 Introduction to Optimization Methods
Winter	ENGM 179 Accounting
	Two M.E.M. free electives
Spring	ENGM 180 Corporate Finance
	ENGM 183 Operations Management
	M.E.M. free elective

## M.E.M. PROGRAM OPTIONS

Students have the option to target their M.E.M. studies toward a specific field of interest. Five possible focus areas are listed below with corresponding elective courses from which students may choose in order to complete their M.E.M. program.

### Healthcare Systems Focus

Students interested in applying engineering management and systems engineering to the healthcare industry may choose electives offered at Thayer School, Tuck School of Business, and The Dartmouth Institute for Health Policy & Clinical Practice (TDI). Additionally, they may choose an internship at a hospital or healthcare company to complete the ENGG 390 project. The opportunity to explore independent study and research projects associated with The Dartmouth Center for Health Care Delivery Science is also available to students. Examples of M.E.M. healthcare electives:

ENGS 160 Biotechnology and Biochemical Engineering  
ENGS 165 Biomaterials  
ENGS 167 Medical Imaging  
ENGS 169 Intermediate Biomedical Engineering  
ENGM 189 Medical Device Development (.5 credit)  
TDI - ECS 111 Critical Issues in Health and Health Care  
TDI - ECS 115 Strategic & Financial Management of Health Care Institutions  
TDI - ECS 121 Decision and Cost-Effective Analysis: An Introduction  
Tuck School - Contemporary Issues in Biotechnology  
Tuck School - Business of Healthcare  
Tuck School - Medical Care and the Corporation  
Tuck School - Management of Healthcare Organizations  
Tuck School - Structure, Organization, and Economics of the Healthcare Industry

### Energy and Environmental Focus

Students interested in applying engineering management to energy and environmental concerns may choose electives offered at Thayer School, Tuck School of Business, and environmental law courses offered at Vermont Law School located in South Royalton, Vermont. Additionally, they may choose to accept an internship at an energy or environmental company to complete the ENGG 390 project. Examples of M.E.M. energy and environmental electives:

ENGS 171 Industrial Ecology  
ENGS 172 Climate Change and Engineering  
ENGG 173 Energy Utilization  
ENGG 174 Energy Conversion  
ENGS 175 Energy Systems  
ENGS 261 Biomass Energy Systems  
Tuck School - Business and Climate Change  
Vermont Law School - Energy Law and Policy in a Carbon-Constrained World  
Vermont Law School - Energy Regulation, Markets and the Environment

### Manufacturing and Operations Focus

Students interested in applying engineering management within the manufacturing industry or in an operations department may choose electives offered at Thayer School or the Tuck School of Business. Additionally, they may choose to accept an internship at a manufacturing company or undertake project to improve operations within a company to complete the ENGG 390 project. Examples of M.E.M. manufacturing and operations electives:

ENGM 185 Topics in Manufacturing Design and Processes  
ENGM 186 Technology Project Management  
Tuck School - Management of Service Operations  
Tuck School - Advanced Business Analytics  
Tuck School - Operations Strategy  
Tuck School - Professional Decision Modeling  
Tuck School - Tools for Improving Operations

### Entrepreneurial Focus

Students interested in starting a high-technology company might choose entrepreneurial electives offered at Thayer School and Tuck School of Business. Additionally, they may choose an entrepreneurial internship or project for ENGG 390. Practical experience can be gained by working with Thayer School professors who have patented their work and established successful businesses. Strategic advice, mentoring, and networking information are available through the Dartmouth Entrepreneurial Network. Examples of M.E.M. entrepreneurial electives:

ENGM 188 Law, Technology, and Entrepreneurship  
 Tuck School - Introduction to Entrepreneurship  
 Tuck School - Advanced Entrepreneurship  
 Tuck School - Entrepreneurial Finance  
 Tuck School - Leading Entrepreneurial Organizations  
 Tuck School - Entrepreneurship in the Social Sector 1  
 Tuck School - Entrepreneurship in the Social Sector 2

### Management of Design Focus

Students interested in applying engineering management and systems engineering studies toward preparation in managing technology design efforts (e.g., in the fields of chemical process design, electronics design, product design, and mechanical design) may choose appropriate electives offered at Thayer School or Tuck School of Business. In addition, they may choose an ENGG 390 internship that is focused on design and/or management of design. Examples of M.E.M. management of design electives:

ENGS 125 Power Electronics and Electromechanical Energy Conversion  
 ENGS 126 Analog Integrated Circuit Design  
 ENGS 128 Advanced Digital System Design  
 ENGS 146 Computer-Aided Mechanical Engineering Design  
 ENGS 157 Chemical Process Design  
 ENGS 158 Chemical Kinetics and Reactors  
 ENGS 171 Industrial Ecology  
 ENGG 173 Energy Utilization  
 ENGS 176 Design for Manufacturing  
 ENGM 186 Technology Project Management

Note that upper division engineering sciences courses such as ENGS 65, 73, 75, and 76, coupled with extra faculty-supervised student work, can also count toward the management of design focus area.

### Duke University Exchange

Thayer School M.E.M. students may choose to spend their second fall term at Duke University taking equivalent courses in Duke's Master of Engineering Management program.

### **M.E.M. PROGRAM DIRECTORS**

**Benoit Cushman-Roisin**, Interim Director  
Professor of Engineering

**Edward J. March**, Interim Co-Director  
Adjunct Professor of Engineering

**Ross A. Gortner**  
Associate Director

### **M.E.M. FACULTY**

**Kenneth R. Baker**  
Nathaniel Leverone Professor of Management, Tuck School of Business  
Adjunct Professor of Engineering

**Mark E. Borsuk**  
Associate Professor of Engineering

**Tillman U. Gerngross**  
Professor of Engineering

**Oliver Goodenough**  
Adjunct Professor of Engineering  
Professor, Vermont Law School

**Mark Laser**  
Research Scientist and Lecturer

**Ronald C. Lasky**  
Professor of Engineering  
Director, Cook Engineering Design Center

**Keith D. Paulsen**  
Robert A. Pritzker Chair in Biomedical Engineering  
Professor of Radiology, Geisel School of Medicine  
Director, Advanced Imaging Center, Dartmouth-Hitchcock Medical Center  
Co-Director, Cancer Imaging and Radiobiology Research Program, Norris Cotton  
Cancer Center

**Vikrant Vaze**  
Assistant Professor of Engineering

**Ulrike G.K. Wegst**  
Associate Professor of Engineering

## M.S.

[engineering.dartmouth.edu/academics/graduate/ms/](http://engineering.dartmouth.edu/academics/graduate/ms/)

The Master of Science in Engineering Sciences program stresses innovative engineering research, advanced levels of engineering skills, and extensive project management experience. Candidates for the degree acquire:

- basic competency in applied mathematics and engineering
- breadth of engineering knowledge through taking a range of courses
- depth of engineering knowledge through focused research as well as courses

In the tradition of founder Sylvanus Thayer, graduate students are encouraged to participate in service activities, such as those sponsored by the Tucker Foundation and the Thayer Council.

### RESEARCH

[engineering.dartmouth.edu/research/](http://engineering.dartmouth.edu/research/)

Research at Thayer School addresses critical needs in three areas of focus:

- Engineering in Medicine—advancing healthcare through technology
- Energy Technologies—addressing challenges of sustainability
- Complex Systems—creating, modeling, and controlling multi-component systems

Research projects in the focus areas involve one or more engineering disciplines:

- |                            |                       |
|----------------------------|-----------------------|
| ■ Biomedical               | ■ Engineering Physics |
| ■ Chemical and Biochemical | ■ Environmental       |
| ■ Computer                 | ■ Materials           |
| ■ Electrical               | ■ Mechanical          |

### PREREQUISITES

A bachelor's degree is required; M.S. students generally hold their degree in engineering or one of the physical sciences.

### ACADEMIC HONOR

All students, upon matriculation, are required to attend a series of workshops in ethics and sign a statement that they agree to abide by the honor principles established by Dartmouth College. A full statement of academic honor is at:

[graduate.dartmouth.edu/services/regulations.html](http://graduate.dartmouth.edu/services/regulations.html)

### RESIDENCY

Students are required to be in residence a minimum of 3 terms.

### NUMBER OF COURSES

Students entering the program with an accredited bachelor's degree in engineering are required to take 6 graduate-level credits beyond any graduate courses taken for the B.E.

Students entering the program without an accredited bachelor's degree in engineering are required to complete 9 graduate-level courses beyond any graduate courses taken for the bachelor's degree, with a minimum of 5 courses in engineering.

Courses taken previously, e.g., as an undergraduate, can be used in satisfaction of the degree requirements, but do not reduce the total number of courses required unless admission is with advanced standing.

GRADE STANDARDS

With the exception of the thesis, the grade assigned at the completion of any graduate-level course is one of the following:

GRADE	EQUIVALENT	INDICATES
HP (High Pass)	A, A-	Distinctly superior work
P (Pass)	B+, B, B-	Good work
LP (Low Pass)	C+, C, C-	Work deficient but acceptable for graduate credit
CR (Credit)	Passing	Satisfactory work (in courses, where HP, P, or LP grade assignment is inappropriate; not intended as alternative to HP, P, or LP)
NC (No Credit)	D, E	Unsatisfactory work, not acceptable for graduate credit

No more than one LP grade for every 6 courses may be submitted in satisfaction of master's degree requirements. Any student who earns LP or lower in courses that satisfy degree requirements receives a letter of warning from the director of his or her graduate program. A detailed statement on the Student Probation Policy is available from the registrar.

ADVISORS

A faculty advisor aids each student in developing a program, which is submitted to and approved by the Thayer School Graduate Program Committee during the student's first term of residency.

M.S. COURSE OPTIONS

Applied mathematics (choose at least 1)	ENGS 91 Numerical Methods in Computation	1 or more courses
	ENGS 92 Fourier Transforms and Complex Variables	
	ENGS 93 Statistical Methods in Engineering	
	ENGS 100 Methods in Applied Mathematics I	
	ENGS 104 Optimization Methods for Engineering Applications	
	ENGS 105 Computational Methods for Partial Differential Equations I	
	ENGS 106 Numerical Linear Algebra	
Engineering depth (choose at least 3)	Courses in the area of the student's research should be chosen to increase the student's depth of expertise and knowledge. These courses should be chosen in concert with the thesis advisor from the graduate engineering listings.	3 or more courses*
Engineering breadth (choose at least 2)	The remainder of the courses may be any graduate course listing area, with approval of the thesis advisor and the graduate program committee.	2 or more courses*
	Research leading to a written thesis	
	An oral defense of the thesis	

\* Engineering Management courses are not permitted.

## **M.S. THESIS REQUIREMENTS**

The M.S. thesis demonstrates a depth of knowledge in a specific field of engineering research or design. A thesis committee typically consists of 3 Dartmouth faculty members (including the student's thesis advisor); one of the 3 may be from outside the program of study.

The candidate also presents a public oral defense of the thesis, which is conducted by the candidate's thesis committee. A two-week notice of the defense is required. Each student must submit an electronic copy of the notice to the Thayer Registrar for distribution to the faculty and for posting.

A hard copy and a pdf of the thesis must be submitted to the registrar for archiving. Copyright to the thesis is held by the Trustees of Dartmouth College.

## **DUAL DEGREES**

### **B.E./M.S.**

Students who wish to be awarded the B.E. degree simultaneously with the M.S. must have taken a substantial portion of the undergraduate program at Dartmouth or in one of its official exchange programs. Students should plan their programs to satisfy both the M.S. requirements and the ABET criteria for the B.E., and discuss their plans with the M.S. program director.

At least one term prior to the scheduled M.S. thesis defense, the B.E./M.S. candidate submits to the Registrar a Bachelor of Engineering program plan approved by both his/her advisor and the Director of the Bachelor of Engineering program.

### **M.E.M./M.S.**

Students who want to qualify in both research and the practical application of engineering and management may earn the M.S. and M.E.M. degrees simultaneously by completing all the requirements of both degrees.

A separate application to the M.E.M. program is required; the student should work out course choices and funding plans for each degree. Interested students should contact the director of the M.E.M. program.

# M.D./M.S.

[engineering.dartmouth.edu/academics/graduate/mdms/](http://engineering.dartmouth.edu/academics/graduate/mdms/)

The M.D./M.S. program, offered by Thayer School and Geisel School of Medicine, is designed for people who intend to pursue clinical practice and want to develop research skills in a related engineering area. It is also well suited to students who want to better understand technologies they will employ as practicing physicians. The program provides a funded research experience in engineering that is expected to lead to a research publication and provides practice in engineering design and analysis.

Applicants must hold an undergraduate degree in engineering and meet the entrance requirements of each school. Application must be made to each school separately. M.D. students apply to Thayer School in the first, second, or third year of medical school and carry out their M.S. studies in the fourth and part of the fifth year. The schedule provides 12 months to complete the M.S. degree and preserves time in July and August following the third and fourth years for important Geisel School of Medicine activities. The M.S. program requires a minimum of 3 terms in residence at Thayer School.

Years 1 and 2	Geisel School of Medicine
Year 3	Geisel School of Medicine (through August)
Year 4	Thayer (September–June)
Year 5	Geisel School of Medicine (July–August) Thayer (September–November) Geisel School of Medicine December–June)

## M.D./M.S. COURSE OPTIONS

Applied mathematics (choose 1)	ENGs 91 Numerical Methods in Computation	1 course
	ENGs 92 Fourier Transforms and Complex Variables	
	ENGs 93 Statistical Methods in Engineering	
	ENGs 100 Methods in Applied Mathematics I	
	ENGs 104 Optimization Methods for Engineering Applications	
	ENGs 105 Computational Methods for Partial Differential Equations I	
	ENGs 106 Numerical Linear Algebra	
Engineering courses (choose 2)	ENGs 110 Signal Processing	2 courses
	ENGs 130 Mechanical Behavior of Materials	
	ENGs 131 Science of Solid State Materials	
	ENGs 132 Thermodynamics and Kinetics in Condensed Phases	
	ENGs 150 Computational Fluid Dynamics	
	ENGs 155 Intermediate Thermodynamics	
	ENGs 156 Heat, Mass, and Momentum Transfer	
	ENGs 161 Microbial Physiology and Metabolic Engineering (pending approval)	
	ENGs 162 Methods in Biotechnology	
Engineering electives (choose 3)	Select 3 additional graduate engineering courses	3 courses
	Research leading to a written thesis	
	An oral defense of the thesis	



## Ph.D.

[engineering.dartmouth.edu/academics/graduate/phd/](http://engineering.dartmouth.edu/academics/graduate/phd/)

Thayer Ph.D. students acquire technical depth in their chosen area of concentration while simultaneously gaining a breadth of knowledge in related fields. In addition to courses in applied mathematics and engineering, students undertake a multi-year research project, usually part of a larger multidisciplinary project.

In the tradition of founder Sylvanus Thayer, graduate students are encouraged to participate in service activities, such as those sponsored by the Tucker Foundation and the Thayer Council.

Students interested in entrepreneurship can augment their program with the **Ph.D. Innovation Program**, which adds courses that address technology business practices and the art of moving research discoveries to market. Students in this program meet all requirements, including passing an oral qualifying examination and defending a Ph.D. thesis proposal. Specific requirements for the candidates in the Innovation Program are on page 61.

### RESEARCH

[engineering.dartmouth.edu/research/](http://engineering.dartmouth.edu/research/)

Research at Thayer School addresses critical needs in three areas of focus:

- Engineering in Medicine—advancing healthcare through technology
- Energy Technologies—addressing challenges of sustainability
- Complex Systems—creating, modeling, and controlling multi-component systems

Research projects in the focus areas involve one or more engineering disciplines:

- |                            |                       |
|----------------------------|-----------------------|
| ■ Biomedical               | ■ Engineering Physics |
| ■ Chemical and Biochemical | ■ Environmental       |
| ■ Computer                 | ■ Materials           |
| ■ Electrical               | ■ Mechanical          |

### PREREQUISITES

The foundation for doctoral work is undergraduate preparation in science, mathematics, and engineering principles. Applicants must hold a bachelor's or master's degree to be considered for the program. Students who are not prepared to complete the first-year requirements (see page 56) are advised to enter the Thayer School M.S. program and petition later to be admitted to the Ph.D. program. Students who have prior graduate training may be considered for advancement to candidacy after completing one or 2 terms of the first-year doctoral program.

### ACADEMIC HONOR

All students, upon matriculation, are required to attend a series of workshops in ethics and sign a statement that they agree to abide by the honor principles established by Dartmouth College. A full statement of academic honor is at: [graduate.dartmouth.edu/services/regulations.html](http://graduate.dartmouth.edu/services/regulations.html)

### RESIDENCY

Students in the Ph.D. program are expected to spend at least 9 terms in residence, 3 of which will take place after successfully completing the oral qualifying examination.

NUMBER OF COURSES

The program of study is developed based on each student’s background and professional interests in consultation with the advisor and first year advisory committee. Students are required to take 8 to 10 courses, reflecting the distribution in the table below. Students with prior graduate credits may transfer up to 5 courses to count towards this requirement.

Applied mathematics	2-3 courses
Courses directed toward acquiring breadth of knowledge in engineering sciences	2-3 courses
Courses leading to a depth of knowledge in an engineering specialty	4 courses

In addition to engineering and applied mathematics courses, Ph.D. students participate in the following seminars and workshops:

ENGG 195 Seminar on Science, Technology and Society	1 term
ENGG 196 Seminar on Applied Science and Technology	3 terms
ENGG 197 Ph.D. Professional Workshops	1 term
ENGG 198 Research-in-Progress Workshop	annually

GRADE STANDARDS

With the exception of the dissertation, the grade assigned at the completion of any graduate-level course is one of the following:

GRADE	EQUIVALENT	INDICATES
HP (High Pass)	A, A-	Distinctly superior work
P (Pass)	B+, B, B-	Good work
LP (Low Pass)	C+, C, C-	Work deficient but acceptable for graduate credit
CR (Credit)	Passing	Satisfactory work (in courses, where HP, P, or LP grade assignment is inappropriate; not intended as alternative to HP, P, or LP)
NC (No Credit)	D, E	Unsatisfactory work, not acceptable for graduate credit

No more than one LP grade for every 6 courses may be submitted in satisfaction of the degree requirements. Any student who earns LP or lower in courses that satisfy degree requirements receives a letter of warning from the director of his or her graduate program. A detailed statement on the Student Probation Policy is available from the registrar.

FIRST-YEAR PROGRAM PLAN

During the first year of the Ph.D. program, students prepare for formal candidacy by taking courses and participating in faculty-directed research projects.

Each student works with a 3-member special advisory committee, which includes the student’s prospective research advisor and at least one faculty member whose research interests differ significantly from the student’s.

The committee helps each student develop a first-year program of study, which the student submits to the Graduate Programs Office during the first week of the term. A typical first-year program of study includes:

Graduate-level courses completed with a grade of B or higher (can be a combination of Dartmouth courses and courses taken at another institution beyond B.S. or B.E. degree requirements)	6 courses
ENGG 296 Graduate research completed with a grade of B or higher	3 terms

During the first term, the committee helps the student develop a full program plan to fulfill the Ph.D. requirements, which the student submits to the Graduate Program Office before the beginning of the second term.

## FULL PROGRAM PLAN

The Ph.D. program plan includes the remaining engineering courses required plus participation in the following seminars and workshops:

ENGG 195 Seminar on Science, Technology and Society	1 term
ENGG 196 Seminar on Applied Science and Technology	3 terms
ENGG 197 Ph.D. Professional Workshops	1 term (usually taken in one of the latter years in residence)
ENGG 198 Research-in-Progress Workshop	Annual participation during spring break

## ACADEMIC PERFORMANCE REVIEW

At the end of the first 3 terms, students undergo a review of their grades in research and formal coursework. Following this and before the middle of the 5th term, the advisor provides the Registrar with a letter of support describing a student's research performance. Satisfactory progress is required for students to schedule their oral qualifying examination, which is normally taken before or during the 5th term in residence. Students who are not progressing are transferred to the M.S. program with the understanding that they may later request to be reconsidered as Ph.D. candidates.

## PH.D. CANDIDACY YEARS

Once advanced to Ph.D. candidacy, students work with a special advisory committee to make sure that all degree requirements are met. In broad terms, the requirements include:

REQUIREMENT	DEFINITION	DEMONSTRATED BY	SEE PAGE
Technical proficiency	Knowledge of the principles and methods of engineering, applied science, and applied mathematics underlying the anticipated thesis research	Coursework and oral qualifying examination	57
Technical breadth	Knowledge of one or more areas outside of or secondary to the candidate's main area of specialization	Program of study OR defense of research proposal OR a project in an area outside main area of specialization	58
Specialization	Mastery of knowledge in the chosen area of research	Oral defense of a thesis proposal AND a program of study	59
Professional competence	Ability to develop resources in chosen area of research	ENGG 197 Ph.D. Professional Workshops	59
Original research	Significant contribution to engineering knowledge combined with professional expertise in the chosen area of study	Presentation at a professional meeting, manuscript accepted for publication, dissertation, oral defense	59

### Technical Proficiency: Oral Qualifying Examination

The oral qualifying exam (ENGG 194), a set of questions put forward by an oral examination committee to the candidate, normally takes place before or during the 5th term of the student's program, or in exceptional circumstances early in the 6th term. The exam is open to the faculty, but not to the general public.

The committee tests the candidate's knowledge of principles and methods underlying the field in which advanced work is to be performed. The exam covers material selected by the candidate's advisor in consultation with the examining committee and includes coverage of mathematical techniques appropriate to the research area. The structure of the preparation for the examination is flexible. See details at: [engineering.dartmouth.edu/images/uploads/OralQualifyingExam-Details.pdf](http://engineering.dartmouth.edu/images/uploads/OralQualifyingExam-Details.pdf)

The student prepares a description of the planned exam, obtains signatures of the advisor and committee members, and submits this to the graduate program office at least 1 month prior to the exam date.

The examination committee consists of 4 members – the Chair plus 3 Dartmouth faculty examiners, with at least 2 of the examiners from Thayer School. A Thayer faculty member other than the student’s advisor chairs the committee. This chair is assigned by the M.S.-Ph.D. Director. See details at: [engineering.dartmouth.edu/images/uploads/OralQualifyingExam-Details.pdf](http://engineering.dartmouth.edu/images/uploads/OralQualifyingExam-Details.pdf)

The examination committee gives the student a pass, fail or conditional pass result. Students who fail may retake the oral examination—one time only—within the following 3 months. Upon passage of the exam or fulfillment of the conditions of the conditional pass (before the assigned deadline) and with a letter of support from the advisor, the student is admitted to Ph.D. candidacy pending vote by the Thayer School faculty.

**Technical Breadth**

The faculty advisor helps the candidate plan a demonstration of technical breadth, which is approved by the Graduate Program Committee. The plan details one of the following options:

Option 1	A set of courses, taken for credit, outside or secondary to the candidate’s principal area of specialization
Option 2	A focused set of courses, taken for credit, which creates a secondary emphasis in specialization and may involve independent study or research
Option 3	Defense of a research proposal OR an oral examination in an area outside the main area of specialization. The candidate might present a research seminar on the topic with an examination committee of 3 faculty members probing the candidate’s depth of knowledge of the secondary area. This option may be combined with the ENGG 197 Ph.D. Professional Workshops (pages 59). Students who do not pass may be permitted to take the oral examination—one time only—within the following 3 months.
Option 4	A creative design project, completed within a time limit of approximately 30 days, in an area outside the main area of specialization. The project is defined and the candidate’s performance is evaluated by a committee of 3 faculty members appointed by the program director. The committee gives the student a statement of need, and the student proposes a means of satisfying that need in an effective, elegant, and economic manner. The project should display the candidate’s ability to conceive and evaluate alternative solutions; carry out analytical evaluations at levels of approximation suited to the problem and the time limit; and recognize situations in which experimental work is needed. If the time limit prohibits experimentation, the candidate should devise the appropriate experiments and demonstrate how the expected results would aid in the design. Within the 30-day time limit, the candidate submits a written report plus an executive summary. Following an oral presentation of the project, the committee examines and evaluates the candidate’s performance in the project. Students who do not pass may be permitted to revise and resubmit the report—one time only—within the following 3 months.

### Specialization: Thesis Proposal

The candidate demonstrates mastery of an area of specialization by writing and defending a thesis proposal within the first 18 months of candidacy. A thesis committee, approved by the director of the Ph.D. program, advises the candidate on the proposed thesis research and administers the defense of the thesis proposal.

The Ph.D. Examination committee consists of a minimum of 3 full-time Dartmouth faculty members of which a minimum of 2 must be from the Thayer School (including the dissertation advisor) as well as an external member with a faculty equivalent research appointment outside of Dartmouth. The external member may participate in meetings in person or via video conference.

The candidate's proposal—a presentation of the proposed thesis research—explains the scope and importance of the proposed research and plans for its completion. The defense presentation should be understandable, at least in a general way, to students and faculty not in the subject area.

#### Two weeks before the defense, candidates must:

- submit the thesis proposal in writing to their committee.
- submit an electronic copy of the defense notice to the Thayer registrar for distribution to the faculty and for posting.

Students who do not pass may be permitted to defend the proposal—one time only—within the following 3 months.

### Professional Competence: Ph.D. Professional Workshops

The candidate demonstrates professional competence by completing ENGG 197 Ph.D. Professional Workshops, which is offered each winter term by the faculty and outside experts. The workshop emphasizes skills in completing competitive proposals, business funding, patenting, research team organization, teaching, résumé and CV creation, and job search techniques. The candidate generally completes the workshop in one of the latter years in residence.

Each candidate completes a competitive research proposal or a business plan for critique by 2 expert referees selected from among faculty, outside experts, and/or corporate representatives.

Candidates who have submitted a competitive research proposal to a funding agency or a business plan to a venture capitalist or financial institution prior to completing the workshop may petition to have the proposal or business plan fulfill this requirement.

### Original Research

Candidates demonstrate their significant contribution to engineering knowledge and professional expertise in the chosen area of study by performing original research. The Ph.D. Examination committee consists of a minimum of 3 full-time Dartmouth faculty members of which a minimum of 2 must be from the Thayer School (including the dissertation advisor) as well as an external member with a faculty equivalent research appointment outside of Dartmouth. The external member may participate in meetings in person or via video conference.

The research is reviewed through all of the following means:

<b>Presentation</b>	Elements of the research presented at a professional meeting with the candidate as first author
<b>Dissertation</b>	Written abstract followed by detailed explanation of the research, approved and signed by the Ph.D. thesis committee
<b>Oral defense*</b>	Presentation of the dissertation in a forum open to the public
<b>Paper</b>	Elements of the research accepted for publication with the candidate as first author

\* A two-week notice of the defense is required. Each student must submit an electronic copy of the notice to the Thayer Registrar for distribution to the faculty and for posting.

## DISSERTATION ARCHIVING

A hard copy and a pdf of the final dissertation must be submitted to the registrar for archiving. Copyright to the dissertation is held by the Trustees of Dartmouth College.

## CAREER DEVELOPMENT

Thayer School offers Ph.D. candidates optional training in engineering management, development and design, and teaching through ENGG 197 and through Thayer Career Services.

### Engineering Management

Candidates interested in administration, management, and/or organization may obtain an Engineering Management Certificate by completing any 3 of the following Engineering Management courses:

ENGM 179 Accounting  
ENGM 180 Corporate Finance  
ENGM 181 Marketing  
ENGM 183 Operations Management  
ENGM 185 Topics in Manufacturing Design and Processes  
ENGM 186 Technology Project Management  
ENGM 188 Law, Technology, and Entrepreneurship

Candidates may enroll in other Thayer School engineering management courses or, for additional tuition, courses offered by Tuck School.

### Engineering Development and Design

Candidates interested in industrial engineering design and development may elect a 2-term course sequence in design methodology and/or an individual project course.

ENGS 89/90 Engineering Design Methodology  
ENGG 390 Master of Engineering Management Project

### Teaching

Candidates interested in teaching may serve as teaching assistants for one of the undergraduate and graduate courses that has a problem session, tutorial, or laboratory component. In special cases, a candidate may participate in the design and development of laboratory exercises for lecture courses or in the design and development of a special topics course.

Candidates may apply for one of these positions only after they have completed the oral qualifying examination.

More formalized teacher training programs, offered through the Dartmouth Center for the Advancement of Learning, are open to Thayer School Ph.D. candidates. More information at:  
[dartmouth.edu/~dcal/](http://dartmouth.edu/~dcal/)

## Ph.D. Innovation Program

[engineering.dartmouth.edu/academics/graduate/phd/innovation/](http://engineering.dartmouth.edu/academics/graduate/phd/innovation/)

Students in the Ph.D. Innovation Program fulfill all the requirements listed previously for first-year Ph.D. students and Ph.D. candidates. Once admitted to candidacy, the student works with a special advisory committee to make sure that all the requirements for the Innovation Program are met. These include:

<b>Skills development</b>	ENGG 195 Seminar on Science, Technology, and Society	1 term
	ENGG 196 Seminar on Applied Science and Technology	3 terms
	ENGG 197 Ph.D. Professional Workshops (recommended but not required; can be used to write a Small Business Innovation Research [SBIR] proposal)	recommended
	ENGG 198 Research in Progress Workshop (annual participation)	annual
<b>Applied mathematics (choose 2)</b>	ENGS 91 Numerical Methods in Computation	2 courses
	ENGS 92 Fourier Transforms and Complex Variables	
	ENGS 93 Statistical Methods in Engineering	
	ENGS 100 Methods in Applied Mathematics I	
	ENGS 104 Optimization Methods for Engineering Applications	
	ENGS 105 Computational Methods for Partial Differential Equations I	
<b>Engineering depth</b>	ENGS 106 Numerical Linear Algebra	4 courses
	Courses in the area of the student's research, chosen to increase the student's depth of expertise and knowledge. These courses should be selected in concert with the thesis advisor.	
<b>Innovation elective (choose 1)</b>	Any graduate-level technical course in area outside the student's area of core expertise	3 courses
	ENGM 179 Accounting	
<b>Innovation coursework</b>	ENGM 180 Corporate Finance	1 course
	ENGM 188 Law, Technology, and Entrepreneurship (or equivalent course)	
	ENGG 321 Introduction to Innovation	
<b>Internship (ENGG 300)</b>	Students will work in a start-up company (possibly their own) or an R&D department in their general field(s) of interest for up to six months. Prior to starting the Internship, students must see Lori Laventure (111 Cummings) to discuss financial/insurance issues.	

The Innovation track includes all the original research requirements of the Ph.D. See page 59.

# M.D./Ph.D. in Biomedical Engineering

[geiselmed.dartmouth.edu/mdphd/](http://geiselmed.dartmouth.edu/mdphd/)  
[engineering.dartmouth.edu/academics/graduate/md/](http://engineering.dartmouth.edu/academics/graduate/md/)

The M.D./Ph.D. Program in Biomedical Engineering combines the medical curriculum at Geisel School of Medicine with the Ph.D. program at Thayer School. Students must apply to Geisel School of Medicine as well as Thayer School, indicating their specific interests. Both degrees are awarded simultaneously after typically 7 to 8 years of study.

## PREREQUISITES

The foundation for doctoral work is undergraduate preparation in science, mathematics, and engineering principles. Applicants must hold a bachelor's or master's degree to be considered for the M.D./Ph.D. program.

## ACADEMIC HONOR

All students, upon matriculation, are required to attend a series of workshops in ethics and sign a statement that they agree to abide by the honor principles established by Dartmouth College. A full statement of academic honor is at: [graduate.dartmouth.edu/services/regulations.html](http://graduate.dartmouth.edu/services/regulations.html)

## RESIDENCY

M.D./Ph.D. candidates are in residence at Thayer School a minimum of 6 terms, including 3 terms of participation in ENGG 196 Seminar on Applied Science and Technology.

## NUMBER OF COURSES

The candidate with undergraduate engineering training (B.E. or B.S. degree) plus 2 years of medical school training normally takes:

Applied mathematics	3 courses
Engineering courses leading to a depth of knowledge in an engineering specialty	4 courses

In addition to engineering and applied mathematics courses, Ph.D. students participate in the following seminars and workshops:

ENGG 195 Seminar on Science, Technology and Society	1 term
ENGG 196 Seminar on Applied Science and Technology	3 terms
ENGG 197 Ph.D. Professional Workshops	1 term
ENGG 198 Research-in-Progress Workshop	annually



## COURSE OF STUDY

<b>Basic medical phase</b>	Geisel School of Medicine Years 1 and 2 Up to 3 eight-week laboratory rotations
<b>First-year Ph.D. phase</b>	Completion of 6 graduate engineering courses
	Participation in 2 terms of ENGG 196 and one term of ENGG 198
	Initiation of dissertation research with thesis advisor
	Qualification for Ph.D. candidacy
<b>Second-year Ph.D. phase</b>	Oral examination
	Completion of additional graduate courses
	Participation in ENGG 195, ENGG 196-198 seminars and workshops
	Thesis proposal and dissertation research
<b>Final Ph.D. phase</b>	Dissertation research
	Completion of thesis defense
<b>Final medical phase</b>	Geisel School of Medicine Years 3 and 4

## DEGREE REQUIREMENTS

### M.D. Requirements

Candidates complete the 4-year M.D. curriculum. The electives of Year 4 may be fulfilled through Ph.D. dissertation research.

### Ph.D. Requirements

REQUIREMENT	DEFINITION	DEMONSTRATED BY	SEE PAGE
<b>Technical proficiency</b>	Knowledge of the principles and methods of engineering, applied science, and applied mathematics underlying the anticipated thesis research	Coursework and oral qualifying examination	57
<b>Technical breadth</b>	Knowledge of one or more areas outside of or secondary to the candidate's main area of specialization	Years 1 and 2 of Geisel School of Medicine curriculum	58
<b>Specialization</b>	Mastery of knowledge in the chosen area of research	Oral defense of thesis proposal approved by M.D./Ph.D. Biomedical Engineering Committee	59
<b>Professional competence</b>	Ability to develop resources in chosen area of research	ENGG 197 Ph.D. Professional Workshops	59
<b>Original research</b>	Significant contribution to engineering knowledge combined with professional expertise in the chosen area of study	Presentation at a professional meeting, manuscript accepted for publication, dissertation, oral defense	59

# Graduate Admissions

[engineering.dartmouth.edu/academics/admissions/graduate/](http://engineering.dartmouth.edu/academics/admissions/graduate/)

## ADMISSION REQUIREMENTS

### M.E.M. Program

Prospective students for the M.E.M. program should have an accredited bachelor's degree in engineering. Students with a bachelor's degree in a physical science may be admitted on condition that any undergraduate deficiencies be made up through additional coursework.

Graduates of programs other than the Dartmouth College A.B. and the Thayer School Dual-Degree program must submit scores from the Graduate Record Exam (GRE). Students whose native language is not English must also submit evidence of satisfactory completion of Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS) scores.

### M.S. and Ph.D. Programs

Prospective students for the M.S. and Ph.D. programs should have an accredited bachelor's degree in engineering, mathematics, or science. Students with minor program deficiencies may be admitted but will be required to complete undergraduate courses in addition to their graduate courses.

Graduates of programs other than the Dartmouth College A.B. and the Thayer School Dual-Degree program must submit scores from the Graduate Record Exam (GRE). Students whose native language is not English must also submit evidence of satisfactory completion of Test of English as a Foreign Language (TOEFL) or the International English Language Testing System (IELTS) scores.

**Special Students:** Students who do not meet prerequisite requirements for admission may be admitted as special students. However, when no more than the equivalent of one term's work is needed to satisfy prerequisites, students will be considered for admission as regular degree candidates.

**Part-Time Students:** Residents of the Upper Valley region who have a B.S. in engineering or an appropriate math/science program and can meet basic academic requirements may pursue coursework on a part-time basis. Thesis topics will be selected with the approval of a graduate program director.

## APPLICATION PROCEDURE

Prospective students should review the application instructions and apply on-line: [engineering.dartmouth.edu/academics/admissions/graduate/](http://engineering.dartmouth.edu/academics/admissions/graduate/)

For information, prospective students from the U.S. and Canada can call toll-free: 1-888-THAYER6 [1-888-842-9376]

Prospective students from other parts of the world should call: 1-603-646-2606

Supporting documents should be sent to:

Graduate Admissions  
Thayer School of Engineering  
Dartmouth College  
14 Engineering Drive  
Hanover, NH 03755-8000  
[engg.admissions@Dartmouth.edu](mailto:engg.admissions@Dartmouth.edu)

Thayer Application Deadline: January 1 for the following fall term for M.S. and Ph.D. applicants. M.E.M. applicants apply in "rounds" with January 15 as the first deadline. [engineering.dartmouth.edu/academics/admissions/graduate/](http://engineering.dartmouth.edu/academics/admissions/graduate/)

## JOINT-DEGREE APPLICANTS

M.D./M.S. and M.D./Ph.D. applicants must apply to both Thayer School and Geisel School of Medicine.

## Tuition and Expenses

Tuition for the 2014–2015 academic year is \$15,588 per term, which covers instruction, use of instructional facilities, and health care service through the College infirmary.

Students without their own hospital insurance must purchase a Dartmouth College hospital insurance policy for approximately \$2,500 a year.

The total cost of a year, including tuition, books, room, board, and incidentals, will be approximately \$63,000–65,000 for the academic year 2014–2015. Financial aid can significantly lower the yearly cost.

## Financial Aid

For full-time students, Thayer School offers an array of financial aid, including tuition scholarships, fellowships, assistantships, loans, and hourly employment. Special and part-time students are ineligible for Thayer School financial aid.

All awards are contingent upon continued satisfactory performance and academic progress.

Students who want an educational loan must submit a completed “Free Application for Federal Student Aid” (FAFSA) form, downloadable from:  
fafsa.ed.gov

More information is at:  
engineering.dartmouth.edu/academics/admissions/financial-aid/  
or graduate.dartmouth.edu/funding/

## FINANCIAL AID FOR M.E.M. STUDENTS

M.E.M. financial aid is need-based and is in the form of partial tuition scholarships. After the M.E.M. internship or any leave term during the M.E.M. program, the student is expected to contribute a minimum of \$3,000 toward tuition.

At the time of application, full-time students in the M.E.M. program must submit the PROFILE application available at:  
profileonline.collegeboard.com

Awards are made annually on an academic year basis.

**Hourly Teaching Assistantships and Other Employment.** Teaching assistantships are available to well qualified students. A teaching assistant is paid hourly to assist with grading, problem sessions, and/or lab work. Assignments are made on a term-by-term basis. Other limited hourly employment is also available to qualified students.

Hourly rates depend on the nature of the work and the student’s ability. Normally work is limited to no more than 12 hours per week during academic terms and 40 hours per week between terms and during off-terms. Hourly employment may not exceed a total of 40 hours per week from any and all College sources.

**Partial Tuition Scholarships.** Scholarships applicable to tuition charges are awarded on the basis of need, as demonstrated by the PROFILE application. Scholarships are renewed each academic year contingent upon continued satisfactory academic progress.

**Loans.** M.E.M. students are eligible to apply for federal Stafford Loans, federal Perkins Loans, and DELC Loans through the Dartmouth Financial Aid Office. Application for educational loans requires submission of the Free Application for Federal Student Aid (FAFSA) and the Dartmouth Graduate Financial Aid application form (see above).

FINANCIAL AID FOR M.S. AND PH.D. STUDENTS

Typically, an M.S. or Ph.D. student enters Thayer School with full support on either a Research Assistantship or a Fellowship.

M.S./Ph.D. Stipends 2014–2015

Most M.S. and Ph.D. financial aid includes full or partial tuition costs plus a monthly stipend.

FINANCIAL AID	TUITION	STIPEND
Research Assistantship for Master’s or first-year Ph.D. student	Full tuition	\$2,110 per month
Research Assistantship for Ph.D. candidate	Full tuition	\$2,210 per month
Research Assistantship for Ph.D. candidate who has passed the oral examination and the oral defense of thesis proposal	Full tuition	\$2,310 per month

**Research Assistantships.** Graduate research assistantships, funded by contract research, are available to well-qualified candidates enrolled in degree programs with thesis requirements. Graduate research assistantships normally carry an award of full tuition, a monthly stipend, and credit toward medical insurance if purchased through the College. Partial awards may also be made.

Research assistantship appointments extend over 3 to 4 terms and are made on recommendation of the contract principal investigator with the approval of the director of the M.S. and Ph.D. programs. Graduate research assistants normally work in the area of their research interests and apply the results toward the thesis requirement.

Graduate research assistants may enroll in no more than 2 non-research courses in fall, winter, and spring terms. With the permission of the faculty advisor, enrollment in one non-research course is permitted in the summer term.

Graduate research assistants are expected to devote 20 hours per week to research when enrolled in 2 non-research courses, 30 hours per week when enrolled in one, and essentially full time between terms and when enrolled only for research. They are expected to be in residence full time, including between terms.

Since assistants are not regular employees of Dartmouth College, they do not earn vacation per se. Assistants may anticipate one-half week of time off for each academic term of appointment, to be arranged with their faculty advisor.

Although responsibilities are defined in terms of hours per week, the emphasis is on the quality of the student’s performance. Continuation of any appointment into succeeding terms is conditional upon satisfactory performance and progress toward degree requirements.

Students who accept graduate assistantships may not engage in any additional employment outside or inside Thayer School without prior approval of the director of the M.S. and Ph.D. programs. Such employment is usually limited to 10 hours per week.

**Hourly Teaching Assistantships.** Teaching assistantships are available to well qualified students. A teaching assistant is paid hourly to assist with grading, problem sessions, and/or lab work. Assignments are made on a term-by-term basis. Students who also hold graduate research assistantships or fellowships must have prior approval of the director of M.S./Ph.D. programs and their research advisors to accept an hourly teaching assistant position (or any other employment inside or outside Thayer School).

# Registration

## RESIDENCY

Graduate students enrolled in 2 or more courses are considered full-time students and as being in residence.

## CHECK-IN

All students intending to be in residence must check in at the beginning of each term (see Academic Calendar, page 2) through an on-line check-in process. This practice lets the faculty and administration know who is actually in residence for the new term and facilitates contacting students with individual problems.

A \$50 penalty will be charged for late check-in (10 days after check-in day).

A student who, for good reason, must check in late may petition the registrar for waiver of this charge.

All College financial accounts must be settled prior to check-in. A student who has failed to settle financial accounts will not be allowed to check in.

## COURSE CHANGES

Check-in has no direct connection with the changing of courses. Registered students may change courses through the Internet (using the student “Banner” home page) or at the Office of the Registrar. Each term, a 5-day period is available for adding, dropping, or exchanging courses; no approval is needed. If possible, students should arrange their course load during this period.

During the second 5 class days of a term a student may add or exchange courses by requesting an instructor override for the intended new courses.

## WITHDRAWAL

**Courses.** Until 2 weeks before the last class of the term, students may withdraw from a course at their own discretion. A student needing to withdraw must obtain the instructor’s signature on a drop form and submit it to the registrar before the deadline indicated each term. The course remains on the student’s transcript with the notation “W,” for “withdrew.”

**Degree Programs.** A student may withdraw (i.e., terminate residence) from degree candidacy at any time. If a student withdraws during the first 10 class days, the notation “withdrew for the term, in good standing” will be entered on the transcript. If withdrawal occurs after the first 10 class days, with certification by the instructor of each course that the student is in good standing, the notation “withdrew for the term, in good standing” will be entered on the transcript; otherwise, each course will be entered followed by the notation “withdrew.”

Withdrawal for medical reasons, when verified by the student’s physician, will be entered as such. Students who withdraw from degree candidacy and later wish to resume degree candidacy must petition the director of their degree program in writing for re-admission.

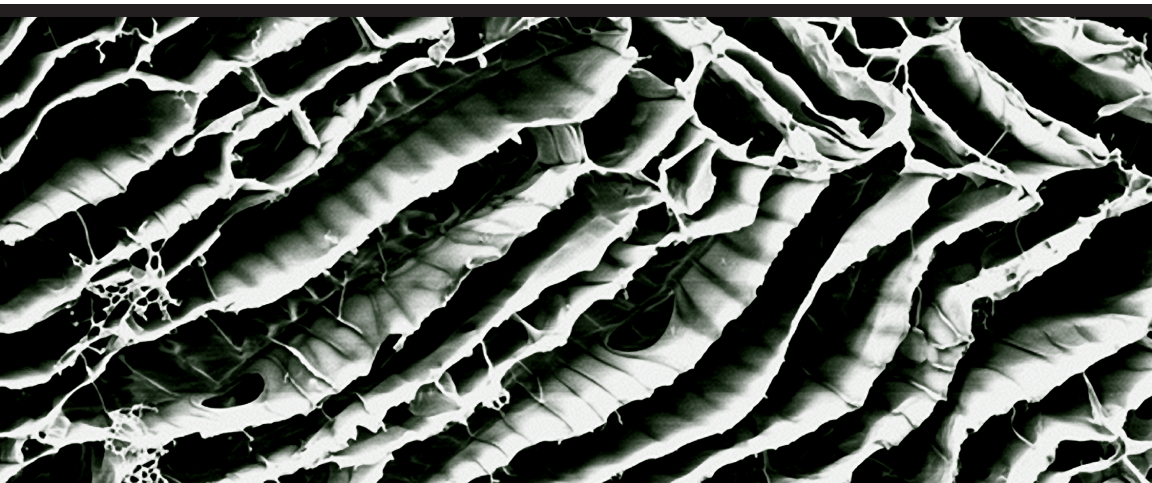
## REFUND POLICY

The Thayer School policy on refund of payments by students who withdraw voluntarily or are dismissed from the School during any term is as follows:

**Tuition.** A full refund is issued to students who withdraw or are dismissed before the beginning of term classes. During the first week, the refund is 90%; during the second and third weeks, 75%; during the fourth week, 50%; during the fifth week, 25%. After the fifth week, there is no refund.

Requests for refunds should be submitted in writing to the Controller of Dartmouth College, 6132 McNutt Hall, Room 103, Hanover, NH 03755, (603) 646-3230. Any balance due the student will be paid within 40 days.

# Undergraduate Courses



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# Undergraduate Courses

[engineering.dartmouth.edu/academics/courses/undergraduate/](http://engineering.dartmouth.edu/academics/courses/undergraduate/)

## A.B. REQUIREMENTS

Most Engineering Sciences (ENGS) courses satisfy requirements for the Engineering Sciences major and can be used for A.B. credit.

## DISTRIBUTIVE CODES

- INT International or Comparative Study
- QDS Quantitative and Deductive Science
- SCI Natural and Physical Science
- SLA Natural and Physical Science with Lab
- TAS Technology or Applied Science
- TLA Technology or Applied Science with Lab
- TMV Systems and Traditions of Thought, Meaning, and Value

## TERM OFFERED

- F Fall
- W Winter
- S Spring
- X Summer

## CLASS TIMES

The number or number-letter combination that follows the term abbreviation is explained in the timetable below. The x-period is time set aside for instructors to use as needed. For some courses, the x-period is an additional class session. Laboratory periods typically begin at 1:30 p.m., although morning and evening sessions may also be held.

	CLASS TIMES	X-PERIOD
8	MTuThF 7:45–8:35	W 7:45–8:35
9S	MTuThF 9:00–9:50	W 9:00–9:50
9L	MWF 8:45–9:50	Th 9:00–9:50
10	MWF 10:00–11:05	Th 12:00–12:50
10A	TuTh 10:00–11:50	W 3:00–3:50
11	MWF 11:15–12:20	Tu 12:00–12:50
12	MWF 12:30–1:35	Tu 1:00–1:50
2	MWF 1:45–2:50	Th 1:00–1:50
2A	TuTh 2:00–3:50	W 4:15–5:05
3A	MTh M 3:00–4:50, Th 4:00–5:50	M 5:00–5:50
3B	TuTh 4:00–5:50	M 5:00–5:50

The Dartmouth College Weekly Schedule Diagram is at:  
[oracle-www.dartmouth.edu/dart/groucho/timetabl.diagram](http://oracle-www.dartmouth.edu/dart/groucho/timetabl.diagram)

## COURSE TIMES

Course times are indicated for 2 years. Not all courses listed are offered each year. Check the Dartmouth Timetable of Class Meetings rather than the ORC to confirm the latest information about course meeting times, instructor, etc.  
[oracle-www.dartmouth.edu/dart/groucho/timetable.main](http://oracle-www.dartmouth.edu/dart/groucho/timetable.main)

## CANCELLATION POLICY

Any listed course may be cancelled if the enrollment is fewer than 5 students.



# Undergraduate Courses by Category

COURSES RECOMMENDED FOR NON-MAJORS		
	ENGS 1	Everyday Technology
	ENGS 2	Integrated Design: Engineering, Architecture, and Building Technology
	ENGS 3	Materials: The Substance of Civilization
	ENGS 4	Technology of Cyberspace
	ENGS 5	Healthcare and Biotechnology in the 21st Century
	ENGS 6	Technology and Biosecurity
	ENGS 7	Contemporary and Historical Perspectives on Medical Imaging
	ENGS 7	Climate Change
	ENGS 8	Materials in Sports Equipment
	ENGS 9	Lasers in Life
	ENGS 10	The Science and Engineering of Digital Imaging
	ENGS 12	Design Thinking
	ENGS 13	Virtual Medicine and Cybercare
	ENGS 14	The Science and Engineering of Music
	ENGS 15	Undergraduate Investigations in Engineering
	ENGS 16	Biomedical Engineering for Global Health
	ENGS 18	System Dynamics in Policy Design and Analysis
	ENGS 19	Microchips in Everyday Life
COURSES FOR MAJORS AND MINORS		
Engineering Sciences Prerequisite	ENGS 20	Introduction to Scientific Computing
Common Core Courses	ENGS 21	Introduction to Engineering
	ENGS 22	Systems
	ENGS 23	Distributed Systems and Fields
Distributive Core Courses	ENGS 24	Science of Materials
	ENGS 25	Introduction to Thermodynamics
	ENGS 26	Control Theory
	ENGS 27	Discrete and Probabilistic Systems
Gateway Courses	ENGS 31	Digital Electronics
	ENGS 32	Electronics: Introduction to Linear and Digital Circuits
	ENGS 33	Solid Mechanics
	ENGS 34	Fluid Dynamics
	ENGS 35	Biotechnology and Biochemical Engineering
	ENGS 36	Chemical Engineering
	ENGS 37	Introduction to Environmental Engineering
Introductory Courses	ENGS 30	Biological Physics
	ENGS 42	Contaminant Hydrogeology
	ENGS 52	Introduction to Operations Research
	ENGS 56	Introduction to Biomedical Engineering

continued

Undergraduate Courses by Category **continued**

COURSES FOR MAJORS AND MINORS		
Upper-Level Courses	ENGS 41	Sustainability and Natural Resource Management
	ENGS 43	Environmental Transport and Fate
	ENGS 44	Sustainable Design
	ENGS 46	Advanced Hydrology
	ENGS 51	Dynamic Modeling of Technological, Social, and Resource Systems
	ENGS 57	Intermediate Biomedical Engineering
	ENGS 60	Introduction to Solid-State Electronic Devices
	ENGS 61	Intermediate Electrical Circuits
	ENGS 62	Microprocessors in Engineered Systems
	ENGS 64	Cellular and Molecular Biomechanics
	ENGS 65	Engineering Software Design
	ENGS 66	Discrete Mathematics in Computer Science
	ENGS 67	Programming Parallel Systems
	ENGS 68	Introduction to Communication Systems
	ENGS 69	Smartphone Programming
	ENGS 71	Structural Analysis
	ENGS 72	Applied Mechanics: Dynamics
	ENGS 73	Materials Processing and Selection
	ENGS 75	Product Design
	ENGS 76	Machine Engineering
	ENGS 80	Ethics and Engineering
	ENGS 84	Reading Course
	ENGS 85	Special Topics
	ENGS 86	Independent Project
	ENGS 87	Undergraduate Investigations
	ENGS 88	Honors Thesis
	ENGS 89	Engineering Design Methodology and Project Initiation
	ENGS 90	Engineering Design Methodology and Project Completion
	ENGS 91	Numerical Methods in Computation
	ENGS 92	Fourier Transforms and Complex Variables
	ENGS 93	Statistical Methods in Engineering

# Undergraduate Course Descriptions

## ENGS 1 Everyday Technology

Offered: 15W, 16W: 11, lab

This course is intended to take the mystery out of the technology that we have grown to depend on in our everyday lives. Both the principles behind and examples of devices utilizing electricity, solid and fluid properties, chemical effects, mechanical attributes and other topics will be discussed. In the associated lab project, students will dissect, analyze, (and possibly revive!) a broken gadget or appliance of their choosing. Enrollment is limited to 50 students.

*No prerequisite*

Instructor: Lasky

Dist: TLA

## ENGS 2 Integrated Design: Engineering, Architecture, and Building Technology

Offered: 15W, 16W: 10A

An introduction to the integrated design of structures and the evolving role of architects and engineers. The course will investigate the idea that design excellence is very often the result of deep collaboration between engineers, architects, and builders and that it is only in relatively recent history that a distinction between these areas of expertise has existed. The historical, social, and architectural impact of structures will be explored and several structures and their designers will be studied in depth. Enrollment is limited to 50 students.

*No prerequisite*

Instructors: May, Wilson

Dist: TAS

## ENGS 3 Materials: The Substance of Civilization

Offered: 15X: 10A, 2A

With the exception of ideas and emotions, materials are the substance of civilization. From the "Iceman's" copper ax to indium phosphide gallium arsenide semiconductor lasers, materials have always defined our world. We even name our epochs of time based on the dominant material of the age: Stone Age, Bronze Age, Iron Age and now Silicon Age. In addition to discussing the nature and processing of metals, polymers, ceramics, glass and electronic materials, this course will analyze the dramatic developments in civilization directly resulting from advances in such materials. The text, Stephen Sass' *The Substance of Civilization*, will be used in the course. Enrollment is limited to 50 students per section.

*No prerequisite*

Instructor: Lasky

Dist: TAS

## ENGS 4 Technology of Cyberspace

Offered: 14F: 10A

This course will cover some basic concepts underlying the "information superhighway." The technologies of high speed networking have stimulated much activity within the federal government, the telecommunications and computer industries, and even social science and popular fiction writing. The technical focus will be on communications technologies, information theory, and the communications requirements of video (standard and ATV), speech (and other audio), text data. Social, economic, and policy issues will be an integral part of the course. Enrollment is limited to 30 students.

*No prerequisite*

Instructor: Taylor

Dist: TAS

### **ENG5 5 Healthcare and Biotechnology in the 21st Century**

Offered: 15S, 16S: 2A

Technologies that will impact healthcare in the 21st century are explored, including biology, robotics, and information. Biotechnologies are explored that will be used for the treatment of diseases and the regeneration of missing organs and limbs. Robotics will be explored that will replace parts. This will include artificial organs, robots as replacement for human parts, the human genome project, gene therapy, biomaterials, genetic engineering, cloning, transplantation (auto, allo and xeno), limb regeneration, man-machine interfaces, robotics, prosthetic limbs, artificial organs and joints. This section will also cover ethical issues related to the above topics and issues regarding the FDA and the approval of new medical treatments. We will discuss going beyond normal with respect to the senses, muscles and creating wings. Enrollment is limited to 75 students.

*No prerequisite*

Instructors: Rosen, Robbie

Dist: TAS

### **ENG5 6 Technology and Biosecurity**

Offered: 15S, 16S: 2A

This course will introduce students to the technologies used to combat biological threats to security ranging from pandemic influenza to bioterrorism. In particular, this course will explore the dual role that technology plays in both enhancing and destabilizing security. Specific technologies covered include the use of nanotechnology, synthetic biology, and mass spectrometry. The course considers questions such as: Where can technological solutions have the greatest impact? When can defensive technologies have offensive applications? And, how can we balance the need to regulate potentially dangerous technologies against the need for academic freedom and high tech innovation? Enrollment is limited to 30 students.

*No prerequisite*

Instructor: Hoyt

Dist: TAS

### **ENG5 7 First-Year Seminars in Engineering**

*The following two courses are available only as part of the First-Year Seminar Program.*

#### **ENG5 7 Contemporary and Historical Perspectives on Medical Imaging**

Offered: 15S: 12

Medical imaging has evolved significantly over the last 100 years and has transformed modern medical practice to the extent that very few clinical decisions are made without relying on information obtained with contemporary imaging modalities. The future of medical imaging may be even more promising as new technologies are being developed to observe the structural, functional, and molecular characteristics of tissues at finer and finer spatial scales. This first-year seminar will review the historical development of modern radiographic imaging and discuss the basic physical principles behind common approaches such as CT, ultrasound, and MRI. Contemporary issues surrounding the use of imaging to screen for disease, the costs to the health care system of routine application of advanced imaging technology, and the benefits of the information provided by medical imaging in terms of evidence-based outcomes assessment will be explored. Students will be required to read, present, and discuss materials in class and write position papers articulating and/or defending particular perspectives on the historical development of medical imaging and its contemporary and/or future uses and benefits. Enrollment is limited to 16 students.

Instructor: Paulsen

Dist: TAS

**ENGS 7 Climate Change**

Offered: 15W: 10

Climate change has occurred naturally and frequently over the course of many time scales in the past. America today is engaged in a discussion of current climate change and its cause, ranging from calls for immediate action to denial. This course explores the published scientific literature on the nature and cause of climate change, potential impacts on us, and the implications for our nation's energy issues. Through readings, class discussion, and individual research, we will explore this complex problem; student writing will synthesize results from the literature to clarify the factual basis for their own understanding. Reading will include a number of published papers and selections from textbooks. Students will be required to actively participate in class by leading class discussions and actively engaging in small group activities. In addition students will write two short papers, develop an annotated bibliography, and write a research paper based on the research completed for the annotated bibliography. Enrollment is limited to 16 students.

Instructor: Albert

Dist: TAS

**ENGS 8 Materials in Sports Equipment**

Offered: 15S, 16S: 9L

Sports equipment uses almost every type of material imaginable, as athletes and designers leverage state-of-the-art materials to maximize human efficiency, performance, comfort and safety. As something most people have some familiarity with, active Dartmouth students in particular, it is an excellent subject for an exploration of material characteristics, selection, design, and failure. This course will introduce materials science concepts in a way that is accessible and useful for the non-major. It will exercise student's critical thinking, quantitative and communication skills. In-class demonstrations will allow students to explore material behavior and differences between materials "hands-on" and possible field trips or lab visits will introduce them to some engineering test methods. Finally, this course will demystify terms used by manufacturers and salespeople, and help students, as athletes and consumers, make informed equipment choices. Enrollment is limited to 40 students.

*No prerequisite*

Instructor: Obbard

Dist: TAS

**ENGS 9 Lasers in Life**

Not offered 2014–2015

From its first appearance in 1962 as "an answer looking for a question," lasers have grown in importance to be in every CD/DVD player, supermarket, laser printer, Boeing 767 airplane. Lasers form the basis of the signals sent around the internet. They are used in applications from surveying to acupuncture, from automotive manufacturing to removing tattoos, from creating fusion to eye surgery. Students will learn first-hand about the development of lasers, the applications they fulfill, and the basic concepts by which they can be understood. The course relates the laser story to the basic concepts of technology, such as design, systems analysis, trade-offs, feedback and control. Enrollment is limited to 40 students.

*No prerequisite*

Dist: TLA

**ENGS 10 The Science and Engineering of Digital Imaging**

Offered: 15X: 10

Recent advances in electrical and computer engineering, computer science and applied mathematics have made remarkable digital imaging systems possible. Such systems are affecting everyone today—from eyewitness documentation of social and political events to health care to entertainment to scientific discovery. This course will introduce students to the fundamental concepts underlying a diverse and representative collection of modern digital imaging systems including cell phone cameras, medical imaging systems, space telescopes, computer games and animated movies. Specific attention will be paid to the scientific principles and engineering challenges underlying optics, computer processing chips, image processing software and algorithms, data compression and communication, and digital sensors as well as the basic principles of human vision and cognition. Students will explore and learn the basic science and technology through a combination of in-class lectures and active hands-on experimentation with digital cameras, image processing software and digital video systems. Students will participate in a course-long group project that demonstrates their understanding of and ability to harness these new technologies. Students will be expected to have access to an entry-level digital camera, either standalone or attached to a cell phone or tablet computer. Enrollment is limited to 75 students.

*No prerequisite*

Instructor: Cybenko

Dist: TAS

**ENGS 12 Design Thinking**

Offered: 14F, 15F: 10A

15W, 16W: 10A

15S, 16S: 10A

A foundation course on the cognitive strategies and methodologies that form the basis of creative design practice. Design thinking applies to innovation across the built-environment, including the design of products, services, interactive technology, environments, and experiences. Topics include design principles, human need-finding, formal methodologies, brainstorming, heuristics, thinking by analogy, scenario building, visual thinking, and study of experienced thinkers. Weekly projects and exercises in a variety of media provide practice and development of students' personal creative abilities. Enrollment is limited to 20 students.

*No prerequisite*

Instructor: Robbie

Dist: TAS

**ENGS 13 Virtual Medicine and Cybercare**

Offered: 14F, 15F: 2A

There is a revolution in technology that is occurring in health care. This new technology will dramatically change how health care is delivered in the future.

This course will cover topics related to the virtual human created from bits. This will include virtual reality, augmented reality and datafusion, computer simulation, advanced 3D and 4D imaging techniques, the operating room of the future, minimally invasive surgery, space medicine, teleoperations, telemedicine and telesurgery, internet 2 and cyber-space, artificial intelligence and intelligent agents applied to medicine, and the national library of medicine virtual human project.

We will also discuss the FDA approval of computer simulators, robotic surgeons, and the ethics of robots doing surgery. In addition we will discuss the medical library of the future, teleconferencing and the use of interactive media in healthcare education. We will also discuss computerized patient records (CPR) and clinical information systems. Enrollment is limited to 48 students.

*No prerequisite*

Instructors: Rosen, Robbie

Dist: TAS

### ENGS 14 The Science and Engineering of Music

Offered: 15W, 16W: 12

Almost everyone enjoys some forms of music, but few are familiar with the science and engineering that make music possible. In this course students are invited to explore the making of music from technical and scientific perspectives. In particular this covers aspects of acoustics, the workings of musical instruments, and selected aspects of musical theory and audio engineering. Students in the course explore music with many in-class demonstrations and hands-on experimentation. Course topics include how sound is recorded and stored digitally, the composition of sound from a musician's point of view (pitch, chords, harmony and melody) and from an engineer's point of view (frequency, harmonics). The relationships between these two perspectives are then explored. This course does not require proficiency in either music or any particular instrument. Enrollment is limited to 50 students.

*No prerequisite*

Instructor: Hartov

Dist: TAS

### ENGS 15 Undergraduate Investigations in Engineering

Offered: all terms: arrange

An original investigation in a phase of science or engineering under the supervision of a member of the staff. Students electing the course will be expected to have a proposal approved by the department chair and to meet weekly with the staff member supervising the investigation. The course is open to undergraduates who are not majoring in engineering. It may be elected only once, or taken as a one-third course credit for each of three consecutive terms. A report describing the details of the investigation must be filed with the department chair and approved at the completion of the course.

*Prerequisite: Permission of department chair (a one-page proposal submission is required and must be submitted for approval prior to the end of the term preceding the term in which the course will be taken).*

Dist: TAS

### ENGS 16 Biomedical Engineering for Global Health

Offered: 15W, 16W: 2A

The past 20 years have seen an incredible amount of high-tech medical advances, but to what degree have these impacted the health of those living in the developing world? The potential for years of life gained through biomedical technology is tremendous in some of the world's poorest regions, but appropriate design requires an understanding of the clinical, political, and cultural landscape, and a clean-slate approach to developing low-cost, effective tech.

This course offers an exciting opportunity to understand how to design solutions for the most important health challenges of the developing world. Learning goals will be achieved through hands-on experience, including: a laboratory component where we deconstruct, design and build a low-cost medical device, case study discussions on successful global health innovations, and several "teardowns" of common medical devices. Lecturers from Thayer, Tuck School of Business, the Dartmouth Center for Health Care Delivery Science, and Geisel School of Medicine will cover complimentary topics in clinical medicine, healthcare delivery, innovation and medical imaging. A final project will bring everything together by addressing a real health problem with a prototype of a low-cost tech solution. Enrollment is limited to 40 students.

*No prerequisite*

Instructor: Pogue, Elliott

Dist: TAS

**ENGS 18 System Dynamics in Policy Design and Analysis**

Offered: 15W, 16W: 2A

This course introduces systems dynamics, an approach to policy design and analysis based upon feedback principles and computer simulation. The approach is useful for gaining an understanding of the underlying structural causes of problem behavior in social, economic, political, environmental, technological, and biological systems. Goals of this approach are to gain better understanding of such problem behaviors and to design policies aimed at improving them. Lectures and exercises illustrate applications of the approach to real, current problems such as urban decay, resource depletion, environmental pollution, product marketing and distribution, and agricultural planning in an expanding population. The similarity and transferability of underlying feedback characteristics among various applications is emphasized. No prior engineering or computer science experience is necessary.

*Prerequisite:* MATH 3

Instructor: Peterson

Dist: TAS

**ENGS 19 Microchips in Everyday Life**

Offered: 15S, 16S; 3A

This course will be an introductory laboratory/lecture course in which students make microelectronic devices, such as transistors, diodes, resistors and capacitors in the laboratory and understand how they work in lectures. The goal of this course is for each student to obtain hands-on experience in device microfabrication and electronic measurement, as well as to provide an overview over the general trend of lithographic miniaturization and nanotechnology.

*No prerequisite*

Instructor: Scherer

Dist: TLA

**ENGS 20 Introduction to Scientific Computing**

(May not be taken under the non-recording option)

Offered: 14F, 15F: 10

15W, 16W: 10

15S, 16S: 11

This course introduces concepts and techniques for creating computational solutions to problems in engineering and science. The essentials of computer programming are developed using the C and Matlab languages, with the goal of enabling the student to use the computer effectively in subsequent courses. Programming topics include problem decomposition, control structures, recursion, arrays and other data structures, file I/O, graphics, and code libraries. Applications will be drawn from numerical solution of ordinary differential equations, root finding, matrix operations, searching and sorting, simulation, and data analysis. Good programming style and computational efficiency are emphasized. Although no previous programming experience is assumed, a significant time commitment is required.

Students planning to pursue the engineering sciences major are advised to take ENGS 20. Students considering the computer science major or majors modified with computer science should take COSC 1 and COSC 10.

Enrollment is limited to 50 students.

*Prerequisite:* MATH 3 and prior or concurrent enrollment in MATH 8

Instructor: Shepherd (fall, winter), P. Taylor (spring)

Dist: TAS



**ENGS 21 Introduction to Engineering**

Offered: 14F: 10, 15F: 10A                      15W, 16W: 10A                      15S, 16S: 10A

The student is introduced to engineering through participation, as a member of a team, in a complete design project. The synthesis of many fields involving the laws of nature, mathematics, economics, management, and communication is required in the project. Engineering principles of analysis, experimentation, and design are applied to a real problem, from initial concept to final recommendations. The project results are evaluated in terms of technical and economic feasibility plus social significance. Lectures are directed toward the problem, and experiments are designed by students as the need develops. Enrollment is limited to 64 students.

*Prerequisite: MATH 3 or equivalent*

Instructors: Wegst (fall), Collier (winter), I. Baker (spring)                      Dist: TAS

**ENGS 22 Systems**

Offered: 14F, 15F: 2, lab                      15W, 16W: 9L, lab                      15S, 16S: 9L, lab                      15X, 16X: 10, lab

The student is introduced to the techniques of modeling and analyzing lumped systems of a variety of types, including electrical, mechanical, reacting, fluid, and thermal systems. System input will be related to output through ordinary differential equations, which will be solved by analytical and numerical techniques. Systems concepts such as time constant, natural frequency, and damping factor are introduced. The course includes computer and laboratory exercises to enhance the students' understanding of the principles of lumped systems. Students will develop the ability to write MATLAB code. Enrollment is limited to 50 students.

*Prerequisite: MATH 13, PHYS 14, and ENGS 20*

Instructors: Trembly (fall), Zhang (winter), Stauth (spring), Trembly (summer)

Dist: TLA

**ENGS 23 Distributed Systems and Fields**

Offered: 14F, 15F: 2                      15W, 16W: 9L                      15S, 16S: 9L

A study of the fundamental properties of distributed systems and their description in terms of scalar and vector fields. After a summary of vector-field theory, the formulation of conservation laws, source laws, and constitutive equations is discussed. Energy and force relations are developed and the nature of potential fields, wave fields, and diffusion fields examined. A survey of elementary transport processes is given. Particular attention is given to the relation between the description of systems in terms of discrete and distributed parameters. Applications are chosen primarily from fluid mechanics, electromagnetic theory, and heat transfer. Includes a set of laboratories.

*Prerequisite: ENGS 22, or equivalent*

Instructors: Phan (fall), Hansen (winter), Trembly (spring)                      Dist: TAS

**ENGS 24 Science of Materials**

Offered: 15W, 16W: 10, lab                      15S, 16S: 10, lab

An introduction to the structure/property relationships that govern the mechanical, the thermal, and the electrical behavior of solids (ceramics, metals, and polymers). Topics include atomic, crystalline, and amorphous structures; x-ray diffraction; imperfections in crystals; phase diagrams; phase transformations; elastic and plastic deformation; free electron theory and band theory of solids; and electrical conduction in metals and semiconductors. The laboratory consists of an experimental project selected by the student and approved by the instructor. Enrollment is limited to 60 students.

*Prerequisite: PHYS 14 and CHEM 5*

Instructors: Frost, Levey (winter), Liu, Levey (spring)                      Dist: TLA

## ENGS 25 Introduction to Thermodynamics

Offered: 15S, 16S: 2                      15X, 16X: 11

The fundamental concepts and methods of thermodynamics are developed around the first and second laws. The distinctions among heat, work, and energy are emphasized. Common processes for generating work, heat, refrigeration, or changing the physical or chemical state of materials are analyzed. The use of thermodynamic data and auxiliary functions, such as entropy, enthalpy, and free energy, is integrated into the analysis. The numerous problems show how theoretical energy requirements and the limitations on feasible processes can be estimated. Enrollment is limited to 60 students.

*Prerequisite: MATH 13, PHYS 13, ENGS 20 or COSC 1 and COSC 10*

Instructors: Staff (spring), Ackerman (summer) Dist: TAS

## ENGS 26 Control Theory

Offered: 14F, 15F: 9L, lab

The course treats the design of analog, lumped parameter systems for the regulation or control of a plant or process to meet specified criteria of stability, transient response, and frequency response. The basic theory of control system analysis and design is considered from a general point of view. Mathematical models for electrical, mechanical, chemical, and thermal systems are developed. Feedback control system design procedures are established using root-locus and frequency-response methods.

*Prerequisite: ENGS 22*

Instructor: Hartov

Dist: TAS

## ENGs 27 Discrete and Probabilistic Systems

Offered: 14F, 15F: 10A

This course is an introduction to probabilistic methods for modeling, analyzing, and designing systems. Mathematical topics include the fundamentals of probability, random variables and common probability distributions, basic queueing theory, and stochastic simulation. Applications, drawn from a variety of engineering settings, may include measurement and noise, information theory and coding, computer networks, diffusion, fatigue and failure, reliability, statistical mechanics, ecology, decision making, and robust design.

*Prerequisite: MATH 8 and either ENGS 20 or COSC 1 and COSC 10. PHYS 13 or CHEM 5 recommended.*

Instructor: Cybenko

Dist: TAS

## ENG 30 Biological Physics

(Identical to PHYS 30)

Offered: 15S, 16S: 12

Introduction to the principles of physics and engineering applied to biological problems. Topics include the architecture of biological cells, molecular motion, entropic forces, enzymes and molecular machines, and nerve impulses. Enrollment is limited to 20 students.

*Prerequisite: CHEM 5, PHYS 13 and PHYS 14 (or equivalent). PHYS 14 (or equivalent) may be taken concurrently. Students with strong quantitative skills who have taken PHYS 3 and PHYS 4 can enroll with permission of the instructor.*

Instructor: Blencowe

Dist: SCI

**ENGS 31 Digital Electronics**

(Identical to COSC 56)

Offered: 15S, 16S: 12, lab

15X, 16X: 9L, lab

This course teaches classical switching theory including Boolean algebra, logic minimization, algorithmic state machine abstractions, and synchronous system design. This theory is then applied to digital electronic design. Techniques of logic implementation, from Small Scale Integration (SSI) through Application-Specific Integrated Circuits (ASICs), are encountered. There are weekly laboratory exercises for the first part of the course followed by a digital design project in which the student designs and builds a large system of his or her choice. In the process, Computer-Aided Design (CAD) and construction techniques for digital systems are learned.

*Prerequisite: ENGS 20 or COSC 1 and COSC 10*

Instructors: Fossum (spring), Hansen (summer)

Dist: TLA

**ENGS 32 Electronics: Introduction to Linear and Digital Circuits**

(Identical to PHYS 48)

Offered: 15W, 16W: 11, lab

Principles of operation of semiconductor diodes, bipolar and field-effect transistors, and their application in rectifier, amplifier, waveshaping, and logic circuits. Basic active-circuit theory. Introduction to integrated circuits: the operational amplifier and comparator, to include practical considerations for designing circuits with off-the-shelf components. Emphasis on breadth of coverage of low-frequency linear and digital networks, as well as on high order passive and active filter design. Laboratory exercises permit "hands-on" experience in the analysis and design of simple electronic circuits. The course is designed for two populations: a) those desiring a single course in basic electronics, and b) those that need the fundamentals necessary for further study of active circuits and systems.

*Prerequisite: ENGS 22, or equivalent background in basic circuit theory*

Instructor: Odame

Dist: TLA

**ENGS 33 Solid Mechanics**

Offered: 14F, 15F: 11, lab

15W, 16W: 12, lab

15X, 16X: 12, lab

After a brief review of the concepts of rigid body statics, the field equations describing the static behavior of deformable elastic solids are developed. The concepts of stress and strain are introduced and utilized in the development. Exact and approximate solutions of the field equations are used in the study of common loading cases, including tension/compression, bending, torsion, pressure, and combinations of these. In the laboratory phase of the course, various methods of experimental solid mechanics are introduced. Some of these methods are used in a project in which the deformation and stress in an actual load system are determined and compared with theoretical predictions. The course includes several computer exercises designed to enhance the student's understanding of the principles of solid mechanics.

*Prerequisites: MATH 13 and PHYS 13*

Instructors: May (fall), Van Citters (winter), Frost (summer)

Dist: TLA

**ENGS 34 Fluid Dynamics**

Offered: 15W, 16W: 9L, lab

A survey of fundamental concepts, phenomena, and methods in fluid mechanics and their application in engineering systems and in nature. Emphasis is placed on the development and use of the conservation laws for mass, momentum, and energy, as well as on the empirical knowledge essential to the understanding of many fluid-dynamic phenomena. Applications include fluid machinery as well as geophysical, environmental, and biomedical fluid flows.

*Prerequisites: ENGS 23 or equivalent*

Instructor: Epps

Dist: TLA

### **ENGS 35 Biotechnology and Biochemical Engineering**

Offered: 14F, 15F: 9L, lab

A consideration of the engineering and scientific basis for using cells or their components in engineered systems. Central topics addressed include kinetics and reactor design for enzyme and cellular systems; fundamentals, techniques, and applications of recombinant DNA technology; and bioseparations. Additional lectures will provide an introduction to metabolic modeling as well as special topics. The course is designed to be accessible to students with both engineering and life-science backgrounds. This course has a graduate section, see ENGS 160. Enrollment is limited to 25 students.

*Prerequisite:* MATH 3, CHEM 3 or CHEM 5, BIOL 12 or BIOL 13 or permission

Instructor: Gerngross

Dist: TLA

### **ENGS 36 Chemical Engineering**

Offered: 14F, 15F: 10A

This course will expose students to the fundamental principles of chemical engineering and the application of these principles to a broad range of systems. In the first part of the course, aspects of chemical thermodynamics, reaction kinetics, and transport phenomena will be addressed. These principles will then be applied to a variety of systems including industrial, environmental, and biological examples.

*Prerequisite:* ENGS 22, ENGS 25 and CHEM 5

Instructor: Laser

Dist: TAS

### **ENGS 37 Introduction to Environmental Engineering**

Offered: 14F, 15F: 12

A survey of the sources, measurement techniques, and treatment technologies relating to environmental pollution resulting from the activities of humans. The course will be technology-focused, but will also touch on topics related to the implementation of technology in the real world such as public perception, policy and legislation, and choosing between technological alternatives. Technological and other issues will be addressed relating to water pollution, air pollution, solid wastes, and the fate and transport of pollutants in the environment. Consideration of each area will include general background and key concepts, detailed design examples of importance in the area, and case studies/current topics. The course will include guest lectures.

*Prerequisite:* MATH 3 and CHEM 5, or equivalent, or permission

Instructor: Cushman-Roisin

Dist: TAS

### **ENGS 41 Sustainability and Natural Resource Management**

Offered: 15S, 16S: 2A

Natural resources sustain human productivity. Principles of scientific resource management are developed, and prospects for sustainability are explored. Three generic categories of resource are analyzed: exhaustible, living, and renewable. In the first category we emphasize the lifecycle of exploitation including exhaustion, exploration and substitution. In the living category we explore population dynamics under natural and harvested regimes, for fisheries and forests. Finally, the renewable case of water is treated in terms of quantity and quality. Throughout, the intersection of natural, economic, and political behavior is explored in theory via computer simulations; case studies illustrate contemporary management problems and practices.

*Prerequisite:* MATH 13

Instructor: Borsuk

Dist: TAS

**ENG 43 Environmental Transport and Fate**

Offered alternate years: 16W: 11

Introduction to movement and transformation of substances released into the natural environment. Fundamentals of advection, dispersion, and reaction. Aggregation and parameterization of various mixing processes leading to dispersion at larger spatial and temporal scales. Importance of inhomogeneity, anisotropy, and stratification in natural media. Basic principles are illustrated by application to atmospheric, ground water, river, estuarine, coastal, and oceanic pollution problems. Case studies include urban smog, acid rain, Chernobyl fall-out, and stratospheric ozone depletion.

*Prerequisite: MATH 13; ENG 37 or permission*

Instructors: Cushman-Roisin, Plagge

Dist: TAS

**ENG 44 Sustainable Design**

Offered: 15S, 16S: 10A

An interdisciplinary introduction to the principles of design for sustainability, with emphasis on the built environment. Through lectures, readings, discussions, and a major design project, students will learn to design buildings and other infrastructure with low to no impact on the environment. Emphasis is on creative thinking, strategies for managing the complexity of the product life-cycle of the infrastructure, and the thorough integration of human and economic aspects in the design. Homework and project activities provide practice in relevant engineering analyses. Enrollment is limited to 20 students.

*Prerequisite: ENG 21 and ENG 22 or SART 65*

Instructor: Cushman-Roisin

Dist: TAS

**ENG 46 Advanced Hydrology**

(Identical to EARS 76)

Offered: 15S: 2A

A survey of advanced methods used to analyze the occurrence and movement of water in the natural environment. The watershed processes controlling the generation of runoff and streamflow are highlighted and used to explore the transport and fate of sediment and contaminants in watersheds. Throughout the course the ideas and concepts are explored through the primary literature, with emphasis given to methods of observation, measurement, data analysis, and prediction.

*Prerequisites: MATH 3 and EARS 16 or 33 or BIO 53 or ENG 43 or permission of instructor*

Instructor: Renshaw

Dist: TAS

**ENG 51 Dynamic Modeling of Technological, Social, and Resource Systems**

Offered: 15S, 16S: 10A

Lumped element dynamic system modeling can be applied to a broad range of systems well beyond the physical systems emphasized in ENG 22. This course considers examples in technological, social and resource systems. A mix of interactive lectures, case studies and projects is used to build skills in conceptualization, formulation, parameter estimation and analysis for systems with rich feedback structure. The course will examine capabilities and limitations of the resulting models for understanding and analyzing the dynamic interplay among technology, society, and resource systems. For example, technology impacts society in areas such as energy, communication, healthcare, food production, and environmental services. Society, in turn, impacts technology via processes such as consumer demand, public policy, and economic development. Natural, environmental, and human resources support and are impacted by both technology and society. Not open to students who have taken ENG 18.

*Prerequisite: ENG 22*

Instructor: Sullivan

Dist: TAS

### **ENG5 52 Introduction to Operations Research**

Offered: 15W, 16W: 10A

Basic concepts of optimization are introduced as aids in systematic decision-making in engineering contexts. Deterministic optimization is developed in the form of linear and integer programming and their extensions. Probabilistic models are introduced in terms of Markov chains, queuing and inventory theory, and stochastic simulation. The course emphasizes the application of these methods to the design, planning, and operation of complex industrial and public systems.

*Prerequisite:* MATH 8 and MATH 22 or equivalent

Instructor: Santos

Dist: TAS

### **ENG5 56 Introduction to Biomedical Engineering**

Offered: 15S, 16S: 2, lab

This course will survey applications of engineering principles to medical diagnosis/treatment of disease, monitoring/measurement of physiological function, and rehabilitation/ replacement of body dysfunction. Case studies will be used to highlight how engineering has advanced medical practice and understanding. Examples will be drawn from bioinstrumentation, bioelectricity, biotransport, biomaterials, and biomechanics. While investigations will focus primarily on the engineering aspects of related topics, issues surrounding patient safety, public policy and regulation, animal experimentation, etc. will be discussed as appropriate.

*Prerequisite:* PHYS 13 and PHYS 14 (PHYS 14 may be taken concurrently)

Instructor: Hoopes

Dist: TLA

### **ENG5 57 Intermediate Biomedical Engineering**

Offered: 15S: 10

The basic biomedical engineering concepts introduced in ENG5 56 will serve as the foundation for exploring technology in a clinical environment. The specific clinical setting to be explored will be the operating room (OR). This course will introduce a variety of surgical procedures and technologies from an engineering perspective. Areas of focus will include patient monitoring, biophysical tissue properties, general surgical instrumentation, tissue cutting and binding technologies, and optical visualization technologies. In addition, state-of-the-art procedures employing image-guided, minimally invasive, laparoscopic, and robot-assisted surgical technologies will be discussed. The first half of the term will include weekly seminars presented by surgeons describing a particular surgical procedure, the technologies currently used and a surgeon's "wish-list". During the second half of the term, students will undertake a design project aimed at developing a technology that addresses a specific need within the OR. Enrollment is limited to 18 students.

*Prerequisite:* ENG5 23 and ENG5 56 or equivalent

Instructor: Halter

Dist: TAS

### **ENG5 60 Introduction to Solid-State Electronic Devices**

Offered: 15W, 16W: 10A, lab

In this course the physical and operational principles behind important electronic devices such as the solar cell and transistor are introduced. Semiconductor electron and hole concentrations and carrier transport are discussed. Carrier generation and recombination including optical absorption and light emission are covered. P-N junction operation and its application to diodes, solar cells, LEDs, and photodiodes is developed. The field-effect transistor (FET) and bipolar junction transistor (BJT) are then discussed and their terminal operation developed. Application of transistors to bipolar and CMOS analog and digital circuits is introduced. The course is primarily intended for students interested in electronics, including digital, analog, power and energy, both at component and integrated circuit levels. The course may also be useful to students interested in electronic materials, device microfabrication and communications.

*Prerequisite:* ENG5 23

Instructor: Fossum

Dist: TLA

**ENGS 61 Intermediate Electrical Circuits**

Offered: 14F: 10, lab                      16S: arrange, lab

This course will build on ENGS 32, providing a foundation for transistor-level analog and digital circuit design. The course will start with an introduction to the Semiconductor Industry and how it has dramatically altered the modern way of life, resulting in diverse technologies from the iPhone and Facebook to LED lighting and electric transportation. This will lead into basic semiconductor theory and CMOS device models, two-port linearized models, and finally single- and multi-stage amplifiers with applications motivated by wireless communications and biomedical instrumentation. The second half of the class will focus on digital circuits. Topics will include designing and optimizing complex static CMOS in terms of energy, delay, and area for computational blocks and memory arrays (SRAM, DRAM, and FLASH). The class will have weekly labs and a final project that will utilize modern computer-aided design tools (Cadence). The course will prepare the student for advanced study of highly integrated electrical circuits.

*Prerequisite: ENGS 32*

Instructor: Stauth

Dist: TLA

**ENGS 62 Microprocessors in Engineered Systems**

Offered: 15W: 2A, lab

Microprocessors and microcomputers are central components in an ever-increasing number of consumer, industrial, and scientific products. This course extends the design framework developed in ENGS 31 to include these high integration parts. Students are introduced to simple and advanced microcomputers, their supporting peripheral hardware, and the hardware and software tools that aid designers in creating embedded system controllers. Laboratory projects will cover basic microprocessor behavior, bus interfaces, peripheral devices, and digital signal processing. Enrollment is limited to 30 students.

*Prerequisite: ENGS 20 and ENGS 31*

Instructor: Taylor

Dist: TLA

**ENGS 65 Engineering Software Design**

Offered: 15W: 3B

As a successor to ENGS 20, this course covers intermediate topics in programming and software design with an emphasis on engineering applications. Students will learn software design principles and basic data structures. Topics covered will include object-oriented design, user interface design, lists, stacks, queues, binary trees, hash tables, and simulation. Students will learn techniques for developing maintainable, extensible, and understandable software.

*Prerequisite: ENGS 20 or COSC 1 and COSC 10*

Instructor: Santos

Dist: TAS

**ENGS 66 Discrete Mathematics in Computer Science**

(Identical to COSC 30; also see MATH 19)

Offered: 14F: 2                      15W: 11

This course integrates discrete mathematics with algorithms and data structures, using computer science applications to motivate the mathematics. It covers logic and proof techniques, induction, set theory, counting, asymptotics, discrete probability, graphs, and trees. MATH 19 is identical to COSC 30 and may substitute for it in any requirement.

*Prerequisite: ENGS 20 or COSC 1 and COSC 10 or advanced placement*

Instructor: Chakrabarti (fall), Jayanti (winter)

Dist: QDS

### **ENGS 67 Programming Parallel Systems**

(Identical to COSC 63)

**Offered:** 14F: 2A, lab

Multi-core processors are now ubiquitous in most personal computers. These are the fundamental computer-engineering building blocks for high-performance servers, blade farms, and cloud computing. In order to utilize these devices in large systems they must be interconnected through networking and collectively programmed. This hands-on system-engineering course offers students the opportunity to explore problem-solving techniques on a high-performance multi-computer containing quad-core processors. The course involves weekly programming laboratories that teach POSIX thread, UDP and TCP network, and MPI style programming techniques. These techniques are explored in the context of scalable problem solving methods applied to typical problems in science and engineering ranging from client-server sensing and data repositories, to numerical methods, gaming and decision support. All laboratories will be conducted in the C programming language and proficiency in C is required. Enrollment is limited to 30 students.

*Prerequisite:* ENGS 20 or COSC 50

Instructor: Taylor

Dist: TLA

### **ENGS 68 Introduction to Communication Systems**

**Offered:** 15W, 16W: 2

This course provides an introduction to communication systems. The focus is on the deterministic aspects of analog and digital systems. The student is introduced to modeling and analyzing signals in the time and frequency domains. Modulation techniques are addressed as well as sampling, multiplexing, line coding, and pulse shaping. Recent developments in communication systems are briefly discussed.

*Prerequisite:* Prior or concurrent enrollment in ENGS 22, ENGS 27 and ENGS 92 strongly recommended

Instructor: Testorf

Dist: TAS

### **ENGS 69 Smartphone Programming**

(Identical to COSC 65, COSC 165)

**Offered:** 15W: 11

This course teaches students how to design, implement, test, debug and publish smartphone applications. Topics include development environment, phone emulator, key programming paradigms, UI design including views and activities, data persistence, messaging and networking, embedded sensors, location based services (e.g., Google Maps), cloud programming, and publishing applications. Concepts are reinforced through a set of weekly programming assignments and group projects. Enrollment limited to 60 students.

*Prerequisite:* COSC 10

Instructor: Campbell

Dist: TAS

### **ENGS 71 Structural Analysis**

**Offered:** 15S, 16S: 10

An introduction to the behavior of structural systems (including examples of buildings, space structures, and mechanical systems), with an emphasis on modeling and approximating behavior. Classical and computational analysis methods for structural load flow through basic three-dimensional structures; methods of approximating the response of planar structures; methods of determining deformations in planar, statically determinate structure; actions and deformations in statically indeterminate structures, using both flexibility/compatibility methods and stiffness/equilibrium methods (including an introduction to matrix methods). A structural system of choice will be redesigned to improve performance.

*Prerequisite:* ENGS 20 or COSC 1 and COSC 10 and ENGS 33

Instructor: May

Dist: TAS



**ENG 72 Applied Mechanics: Dynamics**

Offered: 14F, 15F: 9L

The fundamentals of dynamics with emphasis on their application to engineering problems. Newtonian mechanics including kinematics and kinetics of particles and rigid bodies, work, energy, impulse, and momentum. Intermediate topics will include Lagrange's equations, energy methods, Euler's equations, rigid body dynamics, and the theory of small oscillations.

*Prerequisite:* ENG 22

Instructor: Van Citters

Dist: TAS

**ENG 73 Materials Processing and Selection**

Offered alternate years: 16S: 10A, lab

In this course the basic concepts of materials science introduced in ENG 24 are applied to a variety of materials problems and processes. The course will treat processes and principles relevant to both mechanical and electrical engineering applications. Topics include solidification and crystal growth, joining and bonding techniques, deformation processing, surface coatings and thin film deposition, polymer processing, composite materials, magnetic and dielectric materials, powder metallurgy and ceramics processing, materials selection, failure processes, and quality control. The course will involve laboratory exercises and field trips to local industry. Materials applications will be considered on a case study basis, including aerospace and automotive structures, consumer goods, and high performance sports equipment, electric components, VLSI circuit fabrication and packaging.

*Prerequisite:* ENG 24 and ENG 33 or equivalent

Instructor: Staff

Dist: TLA

**ENG 75 Product Design**

(Can be used for A.B. course count and Engineering Sciences major elective, but may not be used to satisfy B.E. requirements other than design credit.)

Offered: 15W, 16W: 2A

A laboratory course on human-centered product design. A series of design projects form the vehicle for exploring creative strategies for optimizing product design for human use. The course focus includes need-finding, concept development, iterative modeling, prototyping and testing. The goal is synthesis of technical requirements with aesthetic and human concerns. Includes presentations by visiting professional designers. Enrollment is limited to 20 students.

*Prerequisite:* ENG 21 or ENG 89

Instructors: Robbie, Collier

Dist: TAS

**ENG 76 Machine Engineering**

Offered: 14F, 15F: 10A

An introduction to the analysis and synthesis of mechanical components and systems. Lecture topics focus on design and analysis of mechanical components subject to static and fatigue loading conditions, deformation, and buckling. Power transmission shafting, bearings, and gears will be studied in detail. A survey of design requirements for other components—springs, screws, belts, clutches, brakes, roller chains, and welded and riveted connections—will be provided. The class includes laboratory sessions for developing practical skills in design fabrication. A term project emphasizes the synthesis of a working machine to complete a specified task. The project involves the design or selection of components studied, and includes fabrication and demonstration of the machine. Solid modeling software is used as a design tool. Enrollment is limited to 25 students.

*Prerequisite:* ENG 21, ENG 33, and proficiency with solid modeling software

Instructor: Diamond

Dist: TAS

### **ENGs 80 Ethics and Engineering**

May not be used to satisfy A.B. major or B.E. degree requirements

**Not offered 2014–2015**

An examination of the normative dimensions of professional practice, with a practical focus on engineering. Discussion topics will include common morality; ethical theories (virtue, deontological, utilitarian, contractarian); the definition and role of professions in contemporary societies, including theories of professionalism that seek to justify action or inaction in the workplace; the relations among professionals, clients, employers, professional societies, and the service population; and professional codes of conduct. Case studies will include contemporary accidents and issues in advanced technology (genetic engineering, nanotechnology, the machine-human interface). Goals of achievement for the profession will be examined, as expressed by professional societies, educators, and legislation, in the context of emergent globalization of technology and trade. Enrollment is limited to 20 students.

*Prerequisite: Senior standing in the Engineering Sciences major, the physical sciences, or Philosophy; or permission of instructor*

Dist: TMV

### **ENGs 84 Reading Course**

**Offered:** all terms: arrange

Advanced undergraduates occasionally arrange with a faculty member a reading course in a subject not occurring in the regularly scheduled curriculum. This course can only be elected once and either ENGs 84 or 85 may be used toward the Engineering Sciences major, but not both.

*Prerequisite: Permission of the department chair. (Proposed courses should include a full syllabus, resources and student evaluation methods and must be submitted for approval prior to the end of the term preceding the term in which the course will be taken.)*

### **ENGs 85 Special Topics**

**Offered:** all terms: arrange

From time to time a section of ENGs 85 may be offered in order to provide an advanced course in a topic which would not otherwise appear in the curriculum. This course can only be elected once and either ENGs 84 or 85 may be used toward the Engineering Sciences major, but not both.

*Prerequisite: Permission of the department chair*

### **ENGs 86 Independent Project**

**Offered:** all terms: arrange

An individual research or design project carried out under the supervision of a member of the staff. Students electing this course will be expected to carry out preliminary reading during the preceding term. This course may be taken in one term, or as a one-third course credit for each of three consecutive terms. A major written report and oral presentation will be submitted at the completion of the course. ENGs 86 may be counted as an elective in the major if ENGs 89 is taken as the culminating experience. Only one of either ENGs 86 or 88 may be used in satisfaction of the combined A.B. major and B.E. degree requirements.

*Prerequisite: Senior standing in the Engineering Sciences major or Bachelor of Engineering standing and permission of the department chair is required. (One-page proposal submission required and must be submitted for approval prior to the end of the term preceding the term in which the course will be taken.)*

**ENGS 87 Undergraduate Investigations**

(May not be used to satisfy any A.B. major or B.E. degree requirements)

**Offered:** all terms: arrange

An original investigation in a phase of science or engineering under the supervision of a member of the staff. Students electing the course will be expected to carry out preliminary reading during the preceding term and to meet weekly with the staff member supervising the investigation. The course is open to qualified undergraduates with the consent of the department chair, and it may be elected more than once, or taken as a one-third course credit for each of three consecutive terms. A report describing the details of the investigation must be filed with the department chair and approved at the completion of the course.

*Prerequisite: Permission of the department chair. (One-page proposal submission required and must be submitted for approval prior to the end of the term preceding the term in which the course will be taken.)*

**ENGS 88 Honors Thesis**

(Can be counted as an elective in the Engineering Sciences major if ENGS 89 is taken as the culminating experience)

**Offered:** all terms: arrange

Honors version of ENGS 86. A course normally elected by honors students in one term of the senior year. The student will conduct a creative investigation suitable to the major subject under the supervision and guidance of a member of the staff. Students electing this course will be expected to begin the project work at least one term prior to electing ENGS 88 and may choose to conduct the preliminary investigation under ENGS 87. A major written report and oral presentation will be submitted at the completion of the course. Only one of either ENGS 86 or 88 may be used in satisfaction of the combined A.B. major and B.E. degree requirements.

*Prerequisite: Permission of the chair of the Honors program*

**ENGS 89 Engineering Design Methodology and Project Initiation**

**Offered:** 14F, 15F: 2A

This course explores elements of the engineering design process as a means of enhancing student ability in problem definition; development and evaluation of creative alternatives, application and methods of technical and economic analysis, identification and application of ethical and legal constraints, and effective presentation of technical information. Design projects are developed from specifications submitted by industry and other organizations and are pursued over the course of two quarters as a team project, 89/90. Written and oral proposal and progress report are required for the design project during the term. A project advisor is required for each design team to serve as consultant to the team's efforts. ENGS 89, is the first unit of a two-term course sequence 89/90 that must be taken consecutively.

*Prerequisite: Prior to enrollment in ENGS 89, at least six engineering courses must be completed. These include ENGS 21 plus five additional courses numbered 22 to 76.*

**Instructor:** Lotko, Halter

### **ENGS 90 Engineering Design Methodology and Project Completion**

Offered: 15W, 16W: arrange

This course is the second unit in the two-course, team engineering design sequence 89/90. The objective of the course is to develop the student's professional abilities by providing a realistic project experience in engineering analysis, design, and development. Students continue with the design teams formed in ENGS 89 to complete their projects. Design teams are responsible for all aspects of their respective projects, which involve science, innovation, analysis, experimentation, economic decisions and business operations, planning of projects, patents, and relationships with clients. Mid-term and final oral presentations and written reports are required. A faculty member is assigned to each design team to serve as consultant to the team's efforts.

*Prerequisite: ENGS 89*

Instructors: Lotko, Halter

### **ENGS 91 Numerical Methods in Computation**

(Identical to COSC 71)

(Can be used to satisfy graduate degree requirements)

Offered: 14F, 15F: 12

A study and analysis of important numerical and computational methods for solving engineering and scientific problems. The course will include methods for solving linear and nonlinear equations, doing polynomial interpolation, evaluating integrals, solving ordinary differential equations, and determining eigenvalues and eigenvectors of matrices. The student will be required to write and run computer programs.

*Prerequisite: ENGS 20 or COSC 1 and COSC 10; ENGS 22 or MATH 23, or equivalent*

Instructor: Shepherd

Dist: QDS

### **ENGS 92 Fourier Transforms and Complex Variables**

(Identical to PHYS 70)

(Can be used to satisfy graduate degree requirements)

Offered: 14F, 15F: 2

Survey of a number of mathematical methods of importance in Engineering and Physics with particular emphasis on the Fourier transform as a tool for modeling and analysis. Orthogonal function expansions, Fourier series, discrete and continuous Fourier transforms, generalized functions and sampling theory, complex functions and complex integration, Laplace, Z, and Hilbert transforms. Computational Fourier analysis. Applications to linear systems, waves, and signal processing.

*Prerequisite: MATH 46 or ENGS 22 and ENGS 23 or the equivalent*

Instructor: Testorf

Dist: QDS

### **ENGS 93 Statistical Methods in Engineering**

(Can be used to satisfy graduate degree requirements)

Offered: 15W, 16W: 11                      15S, 16S: 12

The application of statistical techniques and concepts to maximize the amount and quality of information resulting from experiments. After a brief introductory summary of fundamental concepts in probability and statistics, topics considered will include probability distributions, sampling distributions, estimation and confidence intervals for parameters of statistical distributions, hypothesis testing, design and analysis of variance for single and multiple-factor experiments, regression analysis, estimation and confidence intervals for parameters of non-statistical models, and statistical quality control.

*Prerequisite: MATH 13 or equivalent*

Instructors: Vaze (winter), Lasky (spring)

Dist: QDS

## Prerequisite Courses for Engineering Sciences

Course offerings for all Dartmouth departments are accessed from:  
dartmouth.edu/~reg

### CHEMISTRY

#### CHEM 5-6 General Chemistry

Offered: 5. 14F: 10, lab

15W: 9, 10, lab

Offered: 6. 14F: 9, lab

15S: 9, 10, lab

An introduction to the fundamental principles of chemistry, including chemical stoichiometry; the properties of gases, liquids, and solids; solutions; chemical equilibria; atomic and molecular structure; an introduction to thermodynamics; reaction kinetics; and a discussion of the chemical properties of selected elements.

The laboratory work emphasizes physical-chemical measurements, quantitative analysis, and synthesis.

An outline of topics for review of secondary school background in preparation for college general chemistry is available from the Department of Chemistry.

*Prerequisites: MATH 3 (or MATH 1 and 2); to take MATH 2 or 3 concurrently with CHEM 5, consult with the department chair; CHEM 5 is a prerequisite for CHEM 6*

Dist: SLA

#### CHEM 10 Honors First-Year General Chemistry

Offered: 14F: 10; lab

CHEM 10 is a general chemistry course for students who have a strong background in chemistry and mathematics and who may have an interest in majoring in the sciences. The course will cover selected general chemistry topics important for higher-level chemistry courses. These include thermodynamics, reaction kinetics, quantum mechanics, and bonding. Laboratory work will emphasize physico-chemical measurements and quantitative analysis.

CHEM 10 is open only to first-year students and enrollment is limited. Admission is by satisfactory performance on a general chemistry proficiency test given during Orientation. Adequate mathematics preparation, equivalent to MATH 3, is also required. CHEM 10 is offered in the fall term and is the prerequisite equivalent to CHEM 5/6. Students who successfully complete CHEM 10 will also be granted credit for CHEM 5, if they have not already been granted such credit.

*Prerequisite: MATH 3 or equivalent; satisfactory performance on the general chemistry proficiency test*

*Supplemental course fee required*

Dist: SLA

## COMPUTER SCIENCE

### COSC 1 Introduction to Programming and Computation

Offered: 14F: 12                      15W, 15S: 2

This course introduces computational concepts that are fundamental to computer science and are useful for the sciences, social sciences, engineering, and digital arts. Students will write their own interactive programs to analyze data, process text, draw graphics, manipulate images, and simulate physical systems. Problem decomposition, program efficiency, and good programming style are emphasized throughout the course. No prior programming experience is assumed.

Dist: TAS

### COSC 10 Problem Solving via Object-Oriented Programming

Offered: 14F: 10, 2                      15W, 15S: 10

Motivated by problems that arise in a variety of disciplines, this course examines concepts and develops skills in solving computational problems. Topics covered include abstraction (how to hide details), modularity (how to decompose problems), data structures (how to efficiently organize data), and algorithms (procedures for solving problems). Laboratory assignments are implemented using object-oriented programming techniques.

*Prerequisite: COSC 1, ENGS 20, or placement through the Advanced Placement exam or the local placement exam*

Dist: TLA

## MATHEMATICS

### MATH 3 Introduction to Calculus

Offered: 14F: 10, 11, 12, 2                      15W: 11, 12, 2

This course is the basic introduction to calculus. Students planning to specialize in mathematics, computer science, chemistry, physics, or engineering should elect this course in the fall term. Others may elect it in the winter.

A study of polynomials and rational functions leads to the introduction of the basic ideas of differential and integral calculus. The course also introduces exponential, logarithmic, and trigonometric functions. The emphasis throughout is on fundamental ideas and problem solving.

MATH 3 is open to all students who have had intermediate algebra and plane geometry. No knowledge of trigonometry is required. The lectures are supplemented by problem sessions.

Dist: QDS

### MATH 8 Calculus of Functions of One and Several Variables

Offered: 14F: 10, 11, 12                      15W: 11, 2                      15S: 10, 11

This course is a sequel to MATH 3 and is appropriate for students who have successfully completed an AB calculus curriculum in secondary school. Roughly half of the course is devoted to topics in one-variable calculus: techniques of integrations, areas, volumes, trigonometric integrals and substitutions, numerical integration, sequences, and series including Taylor series.

The second half of the course generally studies scalar valued functions of several variables. It begins with the study of vector geometry, equations of lines and planes, and space curves (velocity, acceleration, arclength). The rest of the course is devoted to studying different calculus of functions of several variables. Topics include limits and continuity, partial derivatives, tangent planes and differentials, the Chain Rule, directional derivatives and applications, and optimization problems including the use of Lagrange multipliers.

*Prerequisite: MATH 3 or equivalent*

Dist: QDS

### MATH 11 Multivariable Calculus for Two-Term Advanced Placement First-Year Students

Offered: 14F: 9, 11, 12, 2

This course can be viewed as equivalent to MATH 13, but is designed especially for first-year students who have successfully completed a BC calculus curriculum in secondary school. In particular, as part of its syllabus it includes most of the multi-variable calculus material present in MATH 8.

Topics include vector geometry, equations of lines and planes, and space curves (velocity, acceleration, arclength), limits and continuity, partial derivatives, tangent planes and differentials, the Chain Rule, directional derivatives and applications, and optimization problems. It continues with multiple integration, vector fields, line integrals, and finishes with a study of Green's and Stokes' theorem.

Dist: QDS

### MATH 13 Calculus of Vector-Valued Functions

Offered: 14F: 11

15W: 10, 11, 2

15S: 10, 12

This course is a sequel to MATH 8 and provides an introduction to calculus of vector-valued functions. Topics include differentiation and integration of parametrically defined functions with interpretations of velocity, acceleration, arclength and curvature. Other topics include iterated, double, triple and surface integrals including change of coordinates. The remainder of the course is devoted to vector fields, line integrals, Green's theorem, curl and divergence, and Stokes' theorem.

*Prerequisite: MATH 8 or equivalent.*

*Note: First-year students who have received 2 terms on the BC exam generally should take MATH 11 instead. On the other hand, if students have had substantial exposure to multi-variable techniques, they are encouraged to take a placement exam during orientation week to determine if placement into MATH 13 is more appropriate.*

Dist: QDS

### MATH 22 Linear Algebra with Applications

Offered: 14F: 2

15S: 10, 11, 2

15X: arrange

This course presents the fundamental concepts and applications of linear algebra with emphasis on Euclidean space. Significant goals of the course are that the student develop the ability to perform meaningful computations and to write accurate proofs. Topics include bases, subspaces, dimension, determinants, characteristic polynomials, eigenvalues, eigenvectors, and especially matrix representations of linear transformations and change of basis. Applications may be drawn from areas such as optimization, statistics, biology, physics, and signal processing.

Students who plan to take either Mathematics 63 or Mathematics 71 are strongly encouraged to take Mathematics 24.

*Prerequisite: MATH 8*

Dist: QDS

### MATH 23 Differential Equations

Offered: 14F: 10, 2

15W: 12, 2

15S: 11, 12

This course is a survey of important types of differential equations, both linear and nonlinear. Topics include the study of systems of ordinary differential equations using eigenvectors and eigenvalues, numerical solutions of first and second order equations and of systems, and the solution of elementary partial differential equations using Fourier series.

*Prerequisite: MATH 13*

Dist: QDS

PHYSICS

PHYS 13 Introductory Physics I

Offered: 14F, 15W: 10, 11 lab

The fundamental laws of mechanics. Reference frames. Harmonic and gravitational motion. Waves in solids and fluids. Thermodynamics and kinetic theory. PHYS 13, 14, and 19 are designed as a three-term sequence for students majoring in a physical science.

*Prerequisites: MATH 3 and MATH 8; MATH 8 may be taken concurrently*

Dist: SLA

PHYS 14 Introductory Physics II

Offered: 15W: 10                      15S: 10, 11 lab

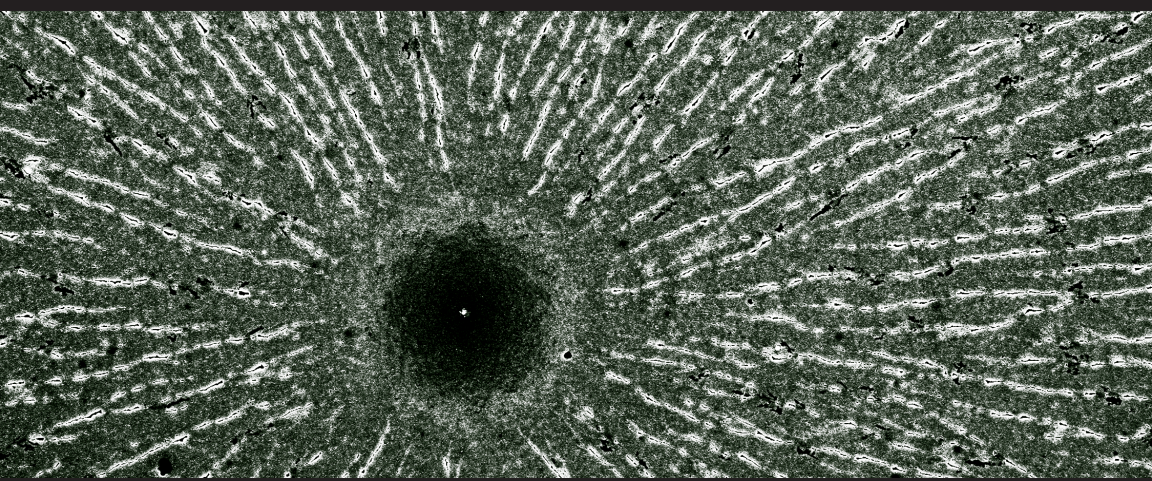
The fundamental laws of electricity and magnetism, Maxwell's equations, waves, electrical and magnetic properties of bulk matter, circuit theory, and optics. Supplemental course fee required.

*Prerequisites: PHYS 13 and MATH 8*

Dist: SLA



# Graduate Courses



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# Graduate Courses

[engineering.dartmouth.edu/academics/courses/graduate/](http://engineering.dartmouth.edu/academics/courses/graduate/)

Undergraduate engineering science majors may take graduate courses for which they are qualified. Not all graduate courses, however, can be used to satisfy A.B. and/or Engineering Sciences major requirements.

- ENGs    Engineering Sciences courses can be used for credit toward the A.B. degree and to satisfy requirements for the Engineering Sciences major.
- ENGG    Engineering courses can be used for credit toward the A.B. degree but do not satisfy requirements for the Engineering Sciences major.
- ENGM    Engineering Management courses satisfy requirements for the M.E.M. degree. They do not satisfy degree requirements for the Engineering Sciences major.

## COURSE NUMBERS

- 100-199    Courses with engineering prerequisites numbered below 100
- 200-299    Courses with engineering prerequisites numbered below 200
- 300-399    Courses with engineering prerequisites numbered below 300

## TERM OFFERED

- F    Fall
- W    Winter
- S    Spring
- X    Summer

## CLASS TIMES

The number or number-letter combination that follows the term abbreviation is explained in the timetable below. The x-period is a period of time set aside for instructors to use as needed. For some courses, the x-period is an additional class session.

	CLASS TIMES	X-PERIOD
8	MTuThF 7:45–8:35	W 7:45–8:35
9S	MTuThF 9:00–9:50	W 9:00–9:50
9L	MWF 8:45–9:50	Th 9:00–9:50
10	MWF 10:00–11:05	Th 12:00–12:50
10A	TuTh 10:00–11:50	W 3:00–3:50
11	MWF 11:15–12:20	Tu 12:00–12:50
12	MWF 12:30–1:35	Tu 1:00–1:50
2	MWF 1:45–2:50	Th 1:00–1:50
2A	TuTh 2:00–3:50	W 4:15–5:05
3A	MTh M 3:00–4:50, Th 4:00–5:50	M 5:00–5:50
3B	TuTh 4:00–5:50	M 5:00–5:50

The Dartmouth College Weekly Schedule Diagram is at:  
[oracle-www.dartmouth.edu/dart/groucho/timetabl.diagram](http://oracle-www.dartmouth.edu/dart/groucho/timetabl.diagram)

## COURSE TIMES

Course times are indicated for 2 years. Not all courses listed are offered each year.

## CANCELLATION POLICY

Any listed course may be cancelled if the enrollment is fewer than 5 students.

# Graduate Courses by Topic

Applied Mathematics	ENGS 91	Numerical Methods in Computation
	ENGS 92	Fourier Transforms and Complex Variables
	ENGS 93	Statistical Methods in Engineering
	ENGS 100	Methods in Applied Mathematics I
	ENGS 104	Optimization Methods for Engineering Applications
	ENGS 105	Computational Methods for Partial Differential Equations I
	ENGS 106	Numerical Linear Algebra
	ENGG 107	Bayesian Statistical Modeling and Computation
	ENGS 200	Methods in Applied Mathematics II
	ENGS 202	Nonlinear Systems
	ENGS 205	Computational Methods for Partial Differential Equations II
	ENGG 309	Topics in Computational Science
Bioengineering	ENGS 160	Biotechnology and Biochemical Engineering
	ENGS 161	Microbial Physiology and Metabolic Engineering (pending approval)
	ENGS 162	Methods in Biotechnology
	ENGS 163	Protein Engineering
	ENGS 165	Biomaterials
	ENGG 166	Quantitative Human Physiology
	ENGS 167	Medical Imaging
	ENGG 168	Biomedical Radiation Transport
	ENGS 169	Intermediate Biomedical Engineering
	ENGS 170	Neuroengineering
	ENGG 261	Biomass Energy Systems
	ENGG 365	Advanced Biomaterials
	ENGG 367	Heat Transfer in Hyperthermia
Computers and Communications	ENGS 110	Signal Processing
	ENGS 111	Digital Image Processing
	ENGS 112	Modern Information Technologies
	ENGS 114	Networked Multi-Agent Systems
	ENGS 115	Parallel Computing
	ENGS 116	Computer Engineering: Computer Architecture
	ENGG 210	Spectral Analysis
	ENGG 212	Communications Theory
	ENGG 310	Advanced Topics in Signals and Systems
	ENGG 312	Topics in Statistical Communication Theory
	ENGG 317	Topics in Digital Computer Design

continued

Graduate Courses by Topic **continued**

Electromagnetics, Optics, Electronics, and Circuits	ENGS 120	Electromagnetic Fields and Waves
	ENGS 122	Semiconductor Theory and Devices
	ENGS 123	Optics
	ENGS 124	Optical Devices and Systems
	ENGS 125	Power Electronics and Electromechanical Energy Conversion
	ENGS 126	Analog Integrated Circuit Design
	ENGS 128	Advanced Digital System Design
	ENGG 129	Instrumentation and Measurements
	ENGS 220	Electromagnetic Wave Theory
	ENGG 324	Microstrip Lines and Circuits
Engineering Management	ENGG 176	Design for Manufacturing
	ENGG 177	Decision-Making under Risk and Uncertainty
	ENGM 178	Technology Assessment
	ENGM 179	Accounting
	ENGM 180	Corporate Finance
	ENGM 181	Marketing
	ENGM 183	Operations Management
	ENGM 184	Introduction to Optimization Methods
	ENGM 185	Topics in Manufacturing Design and Processes
	ENGM 186	Technology Project Management
	ENGM 188	Law, Technology, and Entrepreneurship
	ENGM 189	Medical Device Development (.5 credit)
	ENGM 387	M.E.M. Professional Skills
	ENGG 390	M.E.M. Project
Environmental Science and Engineering	ENGS 171	Industrial Ecology
	ENGS 172	Climate Change and Engineering
	ENGG 173	Energy Utilization
	ENGG 174	Energy Conversion
	ENGS 175	Energy Systems
Fluids, Transport, and Chemical Processes	ENGS 150	Intermediate Fluid Mechanics
	ENGS 151	Environmental Fluid Mechanics
	ENGS 152	Magnetohydrodynamics
	ENGS 153	Computational Plasma Dynamics
	ENGS 155	Intermediate Thermodynamics
	ENGS 156	Heat, Mass, and Momentum Transfer
	ENGS 157	Chemical Process Design
	ENGS 158	Chemical Kinetics and Reactors
	ENGS 250	Turbulence in Fluids

**continued**

**Graduate Courses by Topic** continued

<b>Materials Science</b>	ENGS 130	Mechanical Behavior of Materials
	ENGS 131	Science of Solid State Materials
	ENGS 132	Thermodynamics and Kinetics in Condensed Phases
	ENGS 133	Methods of Materials Characterization
	ENGS 134	Nanotechnology
	ENGS 135	Thin Films and Microfabrication Technology
	ENGG 138	Corrosion and Degradation of Materials
	ENGG 230	Fatigue and Fracture
	ENGG 332	Topics in Plastic Flow and Fracture of Solids
	ENGG 339	Advanced Electron Microscopy
<b>Mechanics, Dynamics and Control</b>	ENGS 142	Intermediate Solid Mechanics
	ENGS 145	Modern Control Theory
	ENGS 146	Computer-Aided Mechanical Engineering Design
	ENGS 147	Mechatronics
	ENGG 148	Structural Mechanics
	ENGG 149	Introduction to Systems Identification
	ENGG 240	Kinematics and Dynamics of Machinery
<b>Research and Independent Study</b>	ENGG 192	Independent or Group Study in Engineering Sciences
	ENGG 296	Graduate Research (1 credit)
	ENGG 297	Graduate Research (2 credits)
	ENGG 298	Graduate Research (3 credits)
<b>Seminars, Workshops, and New Courses</b>	ENGG 194	Ph.D. Oral Qualifier
	ENGG 195	Seminar on Science, Technology, and Society
	ENGG 196	Seminar on Applied Science and Technology
	ENGG 197	Ph.D. Professional Workshops
	ENGG 198	Research-In-Progress Workshops
	ENGG 199	Special Topics in Engineering Sciences
	ENGG 299	Advanced Special Topics in Engineering Sciences
	ENGG 300	Enterprise Experience Project
	ENGG 321	Introduction to Innovation

# Graduate Course Descriptions

## **ENGS 91 Numerical Methods in Computation**

(Identical to COSC 71)

Offered: 14F, 15F: 12

A study and analysis of important numerical and computational methods for solving engineering and scientific problems. The course will include methods for solving linear and nonlinear equations, doing polynomial interpolation, evaluating integrals, solving ordinary differential equations, and determining eigenvalues and eigenvectors of matrices. The student will be required to write and run computer programs.

*Prerequisite: ENGS 20 or COSC 1 and COSC 10; ENGS 22 or MATH 23, or equivalent*

Instructor: Shepherd

Dist: QDS

## **ENGS 92 Fourier Transforms and Complex Variables**

(Identical to PHYS 70)

Offered: 14F, 15F: 2

Survey of a number of mathematical methods of importance in Engineering and Physics with particular emphasis on the Fourier transform as a tool for modeling and analysis. Orthogonal function expansions, Fourier series, discrete and continuous Fourier transforms, generalized functions and sampling theory, complex functions and complex integration, Laplace, Z, and Hilbert transforms. Computational Fourier analysis. Applications to linear systems, waves, and signal processing.

*Prerequisite: MATH 46 or ENGS 22 and ENGS 23 or the equivalent*

Instructor: Testorf

Dist: QDS

## **ENGS 93 Statistical Methods in Engineering**

Offered: 15W, 16W: 11                      15S, 16S: 12

The application of statistical techniques and concepts to maximize the amount and quality of information resulting from experiments. After a brief introductory summary of fundamental concepts in probability and statistics, topics considered will include probability distributions, sampling distributions, estimation and confidence intervals for parameters of statistical distributions, hypothesis testing, design and analysis of variance for single and multiple-factor experiments, regression analysis, estimation and confidence intervals for parameters of non-statistical models, and statistical quality control.

*Prerequisite: MATH 13 or equivalent*

Instructor: Vaze (winter), Lasky (spring)

Dist: QDS

## **ENGS 100 Methods in Applied Mathematics I**

Not offered 2014-2015

Concepts and methods used in the treatment of linear equations with emphasis on matrix operations, differential equations, and eigenvalue problems will be developed following a brief review of analytic function theory. Topics include the Fourier integral, finite and infinite dimensional vector spaces, boundary value problems, eigenfunction expansions, Green's functions, transform techniques for partial differential equations, and series solution of ordinary differential equations. Properties and uses of orthogonal polynomials and special functions such as the hypergeometric, Bessel, Legendre, and gamma functions are included. Applications in engineering and physics are emphasized.

*Prerequisite: ENGS 92 or MATH 33 or MATH 43, with permission of instructor, or the equivalent*

**ENGS 104 Optimization Methods for Engineering Applications**

Offered: 14F, 15F: T, Th 4:00–5:50

An introduction to various methods of optimization and their uses in modern engineering. Students will learn to formulate and analyze optimization problems and apply optimization techniques in addition to learning the basic mathematical principles on which these techniques are based. Topic coverage includes linear programming, nonlinear programming, dynamic programming, combinatorial optimization and Monte Carlo methods.

*Prerequisite: MATH 22 and ENGS 27 or equivalents, or permission of instructor*

Instructor: Cybenko

**ENGS 105 Computational Methods for Partial Differential Equations**

Offered alternate years: 16W: 11

This course concentrates on the numerical solution of partial differential equations commonly encountered in Engineering Sciences. Finite difference and finite element methods are used to solve problems in heat flow, wave propagation, vibrations, fluid mechanics, hydrology, and solid mechanics. The course materials emphasize the systematic generation of numerical methods for elliptic, parabolic, and hyperbolic problems, and the analysis of their stability, accuracy, and convergence properties. Weekly computer exercises will be required to illustrate the concepts discussed in class.

*Prerequisite: MATH 23 and ENGS 91 (COSC 71), or equivalents*

Instructor: Paulsen

**ENGS 106 Numerical Linear Algebra**

(Identical to COSC 271)

Not offered 2014-2015

The course examines, in the context of modern computational practice, algorithms for solving linear systems  $Ax = b$  and  $Ax = \lambda x$ . Matrix decomposition algorithms, matrix inversion, and eigenvector expansions are studied. Algorithms for special matrix classes are featured, including symmetric positive definite matrices, banded matrices, and sparse matrices. Error analysis and complexity analysis of the algorithms are covered. The algorithms are implemented for selected examples chosen from elimination methods (linear systems), least squares (filters), linear programming, incidence matrices (networks and graphs), diagonalization (convolution), sparse matrices (partial differential equations).

*Prerequisite: COSC 71 or ENGS 91. Students are to be familiar with approximation theory, error analysis, direct and iterative technique for solving linear systems, and discretization of continuous problems to the level normally encountered in an undergraduate course in numerical analysis.*

**ENGG 107 Bayesian Statistical Modeling and Computation**

Not offered 2014-2015

This course will introduce the Bayesian approach to statistical modeling as well as the computational methods necessary to implement models for research and application. Methods of statistical learning and inference will be covered for a variety of settings. Students will have the opportunity to apply these methods in the context of their own research or area of application in the form of a term project.

*Prerequisites: ENGS 93 or comparable course in probability and statistics; previous programming experience with Matlab, C, S, R or similar language. (MATH/COSC 71, ENGS 91, COSC 70/170 are appropriate ways to fulfill the programming requirement.)*



### **ENGs 110 Signal Processing**

Offered: 15S, 16S: 10

Continuous and discrete-time signals and systems. The Discrete Fourier Transform and the Fast Fourier Transform. Linear filtering of signals and noise. Characterization of random signals using correlation functions and power spectral densities. Problems will be assigned that require the use of the computer.

*Prerequisite: ENGs 32 and ENGs 92 or equivalents*

Instructor: Hansen

### **ENGs 111 Digital Image Processing**

Offered: 15S, 16S: 9L

Digital image processing has come into widespread use in many fields, including medicine, industrial process monitoring, military and security applications, as well as satellite observation of the earth. This course will cover many aspects of image processing that students will find valuable in their research or personal interest. Topics will include: image sources, computer representation of images and formats, operations on images, and image analysis. In this course we will stretch the conventional notion of images from 2D pixel arrays to include 3D data sets, and we will explore how one can process such stacks of voxels to produce useful information. This course will also touch on some advanced topics in image processing, which may vary based on students' interests. This course will require the completion of a project selected by the student.

*Prerequisites: ENGs 92 and ENGs 93 or equivalents*

Instructor: Hartov

### **ENGs 112 Modern Information Technologies**

Offered: 15S, 16S: 11

This course covers current and emerging information technologies, focusing on their engineering design, performance and application. General topics such as distributed component and object architectures, wireless networking, web computing and information security will be covered. Specific subjects will include Java, CORBA, JINI public key cryptography, web search engine theory and technology, and communications techniques relevant to wireless networking such as Code Division Multiple Access protocols and cellular technology.

*Prerequisite: ENGs 20, ENGs 93 and ENGs 27 or COSC 60. ENGs 93 can be taken concurrently.*

Instructor: Santos

### **ENGs 114 Networked Multi-Agent Systems**

Not offered 2014–2015

Design and analysis of networked systems comprised of interacting dynamic agents will be considered. Inspired by the cohesive behavior of flocks of birds, we design self-organizing engineering systems that mimic a sense of coordinated motion and the capability of collaborative information processing similar to flocks of birds.

Examples include multi-robot networks, social networks, sensor networks, and swarms. The course combines concepts in control theory, graph theory, and complex systems in a unified framework.

*Prerequisite: ENGs 26, MATH 23, or equivalents plus familiarity with MATLAB*



**ENGS 115 Parallel Computing**

Not offered 2014–2015

Parallel computation, especially as applied to large scale problems. The three main topics are: parallel architectures, parallel programming techniques, and case studies from specific scientific fields. A major component of the course is laboratory experience using at least two different types of parallel machines. Case studies will come from such applications areas as seismic processing, fluid mechanics, and molecular dynamics.

*Prerequisite: ENGS 91 (or COSC 71 or equivalent)*

**ENGS 116 Computer Engineering: Computer Architecture**

(Identical to COSC 251)

Not offered 2014–2015

This course provides an introduction to the field of computer architecture. The history of the area will be examined, from the first stored program computer to current research issues. Topics covered will include successful and unsuccessful machine designs, cache memory, virtual memory, pipelining, instruction set design, RISC/CISC issues, and hard-ware/software tradeoffs. Readings will be from the text and an extensive list of papers. Assignments will include homework and a substantial project, intended to acquaint students with open questions in computer architecture.

*Prerequisite: ENGS 31 and COSC 51; COSC 57, COSC 58, or equivalent recommended*

**ENGS 120 Electromagnetic Fields and Waves**

Offered: 15W: 9L

Properties of electromagnetic fields and waves in free space and in conducting and dielectric media. Reflection and transmission at boundaries. Transmission lines. Waveguides.

*Prerequisite: ENGS 23 or PHYS 41*

Instructor: Garmire

**ENGS 122 Semiconductor Theory and Devices**

(Identical to PHYS 126)

Not offered 2014–2015

Elementary physics (classical and quantum) is applied to create models for the behavior of semiconductor devices. The distribution of electron energy, the gap between energy bands, and the mechanisms of current flow are derived. The pn junction and its variations, bipolar junction transistor, junction field effect transistor, and MOSFET devices are studied. Other devices studied are chosen from among opto-electronic and heterojunction devices.

*Prerequisite: ENGS 24, ENGS 32, and ENGS 60 or equivalents*

Instructor: Garmire

**ENGS 123 Optics**

(Identical to PHYS 123)

Offered: 15F: arrange

The physical principles and engineering applications of optics, with an emphasis on optical systems. Geometric optics: ray tracing, first-order analysis, imaging, radiometry. Wave optics: polarization, interference, diffraction, Fourier optics. Sources and detectors. Fiber optic systems.

*Prerequisite: ENGS 23 or PHYS 41, and ENGS 92 or equivalent*

Instructor: Garmire

### **ENGS 124 Optical Devices and Systems**

(Identical to PHYS 124)

Offered alternate years: 15S: 9L

Light has now taken its place beside electricity as a medium for information technology and for engineering and scientific instrumentation. Applications for light include telecommunications and computers, as well as instrumentation for materials science, biomedical, mechanical and chemical engineering. The principles and characteristics of lasers, detectors, lenses, fibers and modulators will be presented, and their application to specific optical systems introduced. The course will be taught in an interdisciplinary way, with applications chosen from each field of engineering. Students will choose design projects in their field of interest.

*Prerequisite:* ENGS 23

Instructor: Garmire

### **ENGS 125 Power Electronics and Electromechanical Energy Conversion**

Offered: 14F, 15F: 11

Controlled use of energy is essential in modern society. As advances in power electronics extend the capability for precise and efficient control of electrical energy to more applications, economic and environmental considerations provide compelling reasons to do so. In this class, the principles of power processing using semiconductor switching are introduced through study of pulse-width-modulated dc-dc converters. High-frequency techniques such as soft-switching are analyzed. Magnetic circuit modeling serves as the basis for transformer, inductor, and electric machine design. Electromechanical energy conversion is studied in relation to electrostatic and electromagnetic motor and actuator design. Applications to energy efficiency, renewable energy sources, robotics, and micro-electromechanical systems are discussed. Laboratory exercises lead to a project involving switching converters and/or electric machines.

*Prerequisite:* ENGS 23 and ENGS 32

Instructor: Sullivan

### **ENGS 126 Analog Integrated Circuit Design**

Offered: 15S, 16S: 2A

Design methodologies of very large scale integration (VLSI) analog circuits as practiced in industry will be discussed. Topics considered will include such practical design considerations as size and cost; technology processes; modeling of CMOS, bipolar, and diode devices; advanced circuit simulation techniques; basic building blocks; amplifiers; and analog systems. A design project is also required in which the student will design, analyze, and optimize a small analog or mixed analog/digital integrated circuit. This design and some homework assignments will require the student to perform analog and digital circuit simulations to verify circuit operation and performance. Lectures will be supplemented by guest lecturers from industry.

*Prerequisite:* ENGS 32 and ENGS 61, or permission of instructor

Instructor: Odame

**ENGS 128 Advanced Digital System Design**

Offered alternate years: 15S: arrange

Field-programmable gate arrays (FPGAs) have become a major fabric for implementing digital systems, rivaling application-specific integrated circuits (ASICs) and microprocessors/microcontrollers, particularly in applications requiring special architectures or high data throughput, such as digital signal processing. Hardware description languages (HDLs) have become the dominant method for digital system design. This course will advance the student's understanding of FPGA design flow and ability to perform HDL-based design and implementation on FPGAs. Topics include: FPGA architectures, digital arithmetic, pipelining and parallelism, efficient design using register transfer level coding and IP cores, computer-aided tools for simulation, synthesis, and debugging. The course is graded on a series of laboratory exercises and a final project.

*Prerequisite: ENGS 31 and ENGS 62 or COSC 51*

Instructor: Hansen

**ENGG 129 Instrumentation and Measurements**

(Can be used by undergraduates for A.B. course count only)

Offered: 15S, 16S: 11

A very significant part of designing electronic instruments involves selecting the appropriate physical devices to translate quantities to be measured into voltages or currents that can be sensed with electronic circuits. The range of sensors and transducers available will be studied with examples from industry and medical instrumentation. The course will explore in some detail the use of analog to digital (A/D) and digital to analog (D/A) converters and their applications. Students will also learn to use complete A/D-microprocessor-D/A systems since these are part of nearly all instruments now. In this course students will learn to build a complete instrument by combining analog and digital components and using advanced algorithms. We will review the basic concepts from analog electronics and real-time event driven programming one needs to understand in order to construct such instruments and experiment through a series of labs. The course will culminate with group projects to induce the students to go through the design process on a problem of their choice.

*Prerequisite: ENGS 31 and ENGS 61 or equivalent*

Instructor: Odame

**ENGS 130 Mechanical Behavior of Materials**

Offered: 14F, 15F: 10

A study of the mechanical properties of engineering materials and the influence of these properties on the design process. Topics include tensorial description of stress and strain, elasticity, plastic yielding under multiaxial loading, flow rules for large plastic strains, microscopic basis for plasticity, viscoelastic deformation of polymers, creep, fatigue, and fracture.

*Prerequisite: ENGS 24 and ENGS 33, or equivalent*

Instructor: Schulson

### ENGS 131 Science of Solid State Materials

Offered: 14F, 15F: 9L

This course provides a background in solid state physics and gives students information about modern directions in research and application of solid state science. The course serves as a foundation for more advanced and specialized courses in the engineering of solid state devices and the properties of materials. The main subjects considered are crystal structure, elastic waves-phonons, Fermi-Dirac and Bose-Einstein statistics, lattice heat capacity and thermal conductivity, electrons in crystals, electron gas heat capacity and thermal conductivity, metals, semiconductors, superconductors, dielectric and magnetic properties, and optical properties. Amorphous solids, recombination, photoconductivity, photoluminescence, injection currents, semiconductor lasers, high temperature superconductors, and elements of semiconductor and superconductor microelectronics are considered as examples.

*Prerequisite: ENGS 24 or PHYS 24 or CHEM 76 or equivalent*

Instructor: Liu

### ENGS 132 Thermodynamics and Kinetics in Condensed Phases

Offered: 15W, 16W: 11

This course discusses the thermodynamics and kinetics of phase changes and transport in condensed matter, with the objective of understanding the microstructure of both natural and engineered materials. Topics include phase equilibria, atomic diffusion, interfacial effects, nucleation and growth, solidification of one-component and two-component systems, solubility, precipitation of gases and solids from supersaturated solutions, grain growth, and particle coarsening. Both diffusion-assisted and diffusion-less or martensitic transformations are addressed. The emphasis is on fundamentals. Applications span the breadth of engineering, including topics such as polymer transformations, heat treatment of metals, processing of ceramics and semiconductors. Term paper.

*Prerequisite: ENGS 24 and ENGS 25, or equivalent*

Instructor: Schulson

### ENGS 133 Methods of Materials Characterization

(Identical to PHYS 128 and CHEM 137)

Offered alternate years: 15W: 10

This survey course discusses both the physical principles and practical applications of the more common modern methods of materials characterization. It covers techniques of both microstructural analysis (OM, SEM, TEM, electron diffraction, XRD), and microchemical characterization (EDS, XPS, AES, SIMS, NMR, RBS and Raman spectroscopy), together with various scanning probe microscopy techniques (AFM, STM, EFM and MFM). Emphasis is placed on both the information that can be obtained together with the limitations of each technique. The course has a substantial laboratory component, including a project involving written and oral reports, and requires a term paper.

*Prerequisite: ENGS 24 or permission*

Instructor: I. Baker

### ENGS 134 Nanotechnology

Offered: 15W, 16W: 10A

Current papers in the field of nanotechnology will be discussed in the context of the course material. In the second half of the term, students will pick a topic of interest and have either individual or small group meetings to discuss literature and research opportunities in this area. The students will prepare a grant proposal in their area of interest. Not open to students who have taken ENGS 74.

*Prerequisite: ENGS 24 or PHYS 19 or CHEM 6, or equivalent*

Instructor: Liu

**ENG 135 Thin Films and Microfabrication Technology**

Offered alternate years: 16W: 2

This course covers the processing aspects of semiconductor and thin film devices. Growth methods, metallization, doping, insulator deposition, patterning, and analysis are covered. There are two major projects associated with the course—an experimental investigation performed in an area related to the student's research or interests, and a written and oral report on an area of thin film technology.

*Prerequisite:* ENGS 24 or equivalent

Instructor: Levey

**ENGG 138 Corrosion and Degradation of Materials**

(Can be used by undergraduates for A.B. course count only)

Not offered 2014–2015

Application of the thermodynamics and kinetics of electrochemical reactions to the understanding of such corrosion phenomena as oxidation, passivity, stress corrosion cracking, and corrosion fatigue. Discussion of methods of corrosion control and prevention, including alloy selection, environmental control, anodic and cathodic protection, and protective coatings. Some treatment of the environmental degradation of non-metals and polymers. Applications to current materials degradation problems in marine environments, petrochemical and metallurgical industries, and energy conversion systems.

*Prerequisites:* ENGS 24 and CHEM 5

**ENG 142 Intermediate Solid Mechanics**

Offered: 15W, 16W: 10

Exact and approximate solutions of the equations of elasticity are developed and applied to the study of stress and deformation in structural and mechanical elements. The topics will include energy methods, advanced problems in torsion and bending, stress concentrations, elastic waves and vibrations, and rotating bodies. Although most applications will involve elastic deformation, post-yield behavior of elastic-perfectly plastic bodies will also be studied. The course will also include numerous applications of finite element methods in solid mechanics.

*Prerequisite:* ENGS 71 or ENGS 76 or equivalent

Instructor: Petrenko

**ENG 145 Modern Control Theory**

Offered: 15S, 16S: 10A

A continuation of ENGS 26, with emphasis on digital control, state-space analysis and design, and optimal control of dynamic systems. Topics include review of classical control theory; discrete-time system theory; discrete modeling of continuous-time systems; transform methods for digital control design; the state-space approach to control system design; optimal control; effects of quantization and sampling rate on performance of digital control systems. Laboratory exercises reinforce the major concepts; the ability to program a computer in a high-level language is assumed.

*Prerequisite:* ENGS 26

Instructor: Phan

**ENG 146 Computer-Aided Mechanical Engineering Design**

Offered: 15S, 16S: 2A

An investigation of techniques useful in the mechanical design process. Topics include computer graphics, computer-aided design, computer-aided manufacturing, computer-aided (finite element) analysis, and the influence of manufacturing methods on the design process. Project work will be emphasized. Enrollment is limited to 24 students.

*Prerequisite:* ENGS 76

Instructor: Diamond

### **ENGS 147 Mechatronics**

Offered: 16S: 3A

Mechatronics is the systems engineering approach to computer-controlled products. This course will integrate digital control theory, real-time computing, software design, sensing, estimation, and actuation through a series of laboratory assignments, complementary lectures, problem sets, and a final project. Topics covered will include microprocessor based real-time computing, digital control, state estimation, signal conditioning, sensors, autonomous navigation, and control architectures for autonomous systems.

*Prerequisite: ENGS 26 or ENGS 145 and two of ENGS 31, ENGS 32, ENGS 33, ENGS 76 or equivalent*

Instructor: Ray

### **ENGG 148 Structural Mechanics**

(Can be used by undergraduates for A.B. course count only)

Offered alternate years: 15W: 10A

Development and application of approximate and “exact” analytical and computational methods of analysis to a variety of structural systems, including trusses, two- and three-dimensional frames, plates and/or shells. Modeling of structural systems as one and multi degree of freedom lumped systems permits analysis under a variety of dynamic loads as well as providing an introduction to vibration analysis.

*Prerequisite: ENGS 33*

Instructor: Phan

### **ENGG 149 Introduction to Systems Identification**

Offered alternate years: 16W: 10A

This course provides the fundamentals of system identification theory and its applications to mechanical, electrical, civil, and aerospace systems. Several state-of-the-art identification algorithms in current engineering practice will be studied. The following topics are covered: discrete-time and continuous-time models, state-space and input-output models, Markov parameters, observer Markov parameters, discrete Fourier transform, frequency response functions, singular value decomposition, least-squares parameter estimation, minimal realization theory, observer/Kalman filter identification, closed-loop system identification, nonlinear system identification, recursive system identification, and introduction to adaptive control.

*Prerequisites: ENGS 22 and ENGS 26, or equivalent*

Instructor: Phan

### **ENGS 150 Intermediate Fluid Mechanics**

Offered: 15S, 16S: 12

Following a review of the basis equations of fluid mechanics, the subjects of potential flow, viscous flows, boundary layer theory, turbulence, compressible flow, and wave propagation are considered at the intermediate level. The course provides a basis for subsequent more specialized studies at an advanced level.

*Prerequisite: ENGS 25, ENGS 34, or permission of the instructor*

Instructor: Epps

### ENG 151 Environmental Fluid Mechanics

Not offered 2014–2015

Applications of fluid mechanics to natural flows of water and air in environmentally relevant systems. The course begins with a review of fundamental fluid physics with emphasis on mass, momentum and energy conservation. These concepts are then utilized to study processes that naturally occur in air and water, such as boundary layers, waves, instabilities, turbulence, mixing, convection, plumes and stratification. The knowledge of these processes is then sequentially applied to the following environmental fluid systems: rivers and streams, wetlands, lakes and reservoirs, estuaries, the coastal ocean, smokestack plumes, urban airsheds, the lower atmospheric boundary layer, and the troposphere. Interactions between air and water systems are also studied in context (for example, sea breeze in the context of the lower atmospheric boundary layer).

*Prerequisite: ENGS 25, ENGS 34, and ENGS 37, or equivalent*

### ENG 152 Magnetohydrodynamics

(Identical to PHYS 115)

Offered alternate years: 15W: 2A

The fluid description of plasmas and electrically conducting fluids including magnetohydrodynamics and two-fluid fluid theory. Applications to laboratory and space plasmas including magnetostatics, stationary flows, waves, instabilities, and shocks.

*Prerequisite: PHYS 68 or equivalent, or permission of the instructor*

Instructor: Lotko

### ENG 153 Computational Plasma Dynamics

(Identical to PHYS 118)

Offered alternate years: 15S: arrange

Theory and computational techniques used in contemporary plasma physics, especially nonlinear plasma dynamics, including fluid, particle and hybrid simulation approaches, also linear dispersion codes and data analysis. This is a “hands-on” numerical course; students will run plasma simulation codes and do a significant amount of new programming (using Matlab).

*Prerequisite: PHYS 68 or equivalent with ENGS 91 or equivalent recommended, or permission of the instructor*

Instructor: Kress

### ENG 155 Intermediate Thermodynamics

Offered: 15S, 16S: arrange

The concepts of work, heat, and thermodynamic properties are reviewed. Special consideration is given to derivation of entropy through information theory and statistical mechanics. Chemical and phase equilibria are studied and applied to industrial processes. Many thermodynamic processes are analyzed; the concept of exergy (availability) is used to evaluate their performance, and identify ways to improve their efficiency.

*Prerequisite: ENGS 25*

Instructor: Frost

### **ENGS 156 Heat, Mass, and Momentum Transfer**

Offered: 15S, 16S: 10

Fundamentals of convection, conduction, radiation, mass, and momentum transport. Basic conservation laws and rate equations in laminar and turbulent flows. Exact solutions. Approximate solutions using boundary layer or integral techniques. Empirical methods. Analysis of engineering systems.

*Prerequisite:* ENGS 25, ENGS 34

Instructor: Hill

### **ENGS 157 Chemical Process Design**

Offered: 15W, 16W: 11

An in-depth exposure to the design of processes featuring chemical and/or biochemical transformations. Topics will feature integration of unit operations, simulation of system performance, sensitivity analysis, and system-level optimization. Process economics and investment return will be emphasized, with extensive use of the computer for simulation and analysis.

*Prerequisite:* ENGS 36

Instructor: Laser

### **ENGS 158 Chemical Kinetics and Reactors**

Offered: 15S, 16S: 12

The use of reaction kinetics, catalyst formulation, and reactor configuration and control to achieve desired chemical transformations. The concepts and methods of analysis are of general applicability. Applications include combustion, fermentations, electrochemistry, and petrochemical reactions.

*Prerequisite:* ENGS 36

Instructor: Laser

### **ENGS 160 Biotechnology and Biochemical Engineering**

Offered: 14F, 15F: 9L, lab

A graduate section of ENGS 35 involving a project and extra class meetings. Not open to students who have taken ENGS 35.

*Prerequisite:* MATH 3, CHEM 3 or CHEM 5, BIOL 12 or BIOL 13 and permission of the instructor

Instructor: Gerngross

### **ENGS 161 Microbial Physiology and Metabolic Engineering (pending approval)**

Offered alternate years: 15W: arrange

A consideration of cellular metabolism, with an emphasis on microbial metabolism and its manipulation in order to produce products of interest. Quantitative descriptions of energy generation, cell growth, and biosynthesis will be addressed in the context of both unstructured and structured models. General principles of metabolic engineering, including metabolic control theory, will be presented and illustrated using case studies. Students will complete a substantial course project related to goal-directed analysis and manipulation of metabolism.

*Prerequisites:* ENGS 160 and a non-introductory course in biochemistry or molecular biology, or permission

Instructors: Lynd



### ENG 162 Methods in Biotechnology

Offered alternate years: 15S: arrange

This is a laboratory based course designed to provide hands on experience with modern biotechnological research, high throughput screening and production tools. The course provides familiarity with processes commonly used in the biotechnology industry. Examples include fermentation systems controlled by programmable logic controllers, down stream processing equipment such as continuous centrifugation, cross flow ultra-filtration and fluidized bed chromatography. The laboratory also demonstrates the substitution of routine molecular biological and biochemical operations by automated liquid handlers and laboratory robots. Students design and develop a bioassay, which is then implemented by laboratory robots for which they have to write their own implementation program. The course has a significant laboratory component. Enrollment is limited to 12 students.

*Prerequisite: One from ENG 35, ENG 160, and ENG 161, or one from BIOL 61, BIOL 64, and BIOL 65*

Instructor: Ackerman

### ENG 163 Protein Engineering

Offered: 15W, 16W: 10

Engineered biomolecules are powering an array of innovations in biotechnology, and this course will familiarize students with key developments in the field. A brief review of important biochemical principles will touch on concepts such as the central dogma of biology, atomic scale forces in protein structures, and the relationship between protein structure and function. Strategies for protein structure modification will then be surveyed, with a particular emphasis on genetic techniques. These discussions will culminate with a detailed examination of evolutionary engineering algorithms that represent state of the art technologies for combinatorial protein design. The development of proteins with practical utility will be highlighted throughout the term using examples and case studies taken from the current literature.

*Prerequisite: One from ENG 35 or 160, and one from CHEM 5 or 10. Alternatively students may have one from CHEM 41, BIOL 40 or Biochem 101. Equivalent courses accepted with instructor's permission.*

Instructor: Ackerman

### ENG 165 Biomaterials

Offered: 15S, 16S: T, Th 8:00–10:00

Consideration of material problems is perhaps one of the most important aspects of prosthetic implant design. The effects of the implant material on the biological system as well as the effect of the biological environment on the implant must be considered. In this regard, biomaterial problems and the bioelectrical control systems regulating tissue responses to cardiovascular and orthopedic implants will be discussed. Examples of prosthetic devices currently being used and new developments of materials appropriate for future use in implantation will be taken from the literature.

*Prerequisite: ENG 24, or equivalent*

Instructor: Van Citters

### **ENGG 166 Quantitative Human Physiology**

(Can be used by undergraduates for A.B. course count only)

Offered: 16S: arrange

Introduction to human physiology using the quantitative methods of engineering and physical science. Topical coverage includes cellular membrane ion transport, Hodgkin-Huxley models and action potentials, musculoskeletal system, cardiovascular physiology, respiratory physiology, and nervous system physiology. Laboratory exercises and a final project delve into the measurement of human physiology, data analysis, and model testing.

*Prerequisite:* ENGS 22 or equivalent; BIOL 12 or BIOL 14 or ENGS 30; ENGS 23 or MATH 23 or BIOL 35 or PEMM 101

Instructor: Pogue

### **ENGS 167 Medical Imaging**

Offered alternate years: 14F: 10

A comprehensive introduction to all major aspects of standard medical imaging systems used today. Topics include radiation, dosimetry, x-ray imaging, computed tomography, nuclear medicine, MRI, ultrasound, and imaging applications in therapy. The fundamental mathematics underlying each imaging modality is reviewed and an engineering picture of the hardware needed to implement each system is examined. The course will incorporate a journal club review of research papers, term tests, and a term project to be completed on an imaging system.

*Prerequisite:* ENGS 92 (may be taken concurrently)

Instructor: Pogue

### **ENGG 168 Biomedical Radiation Transport**

Offered alternate years: 15F: 10

This course will provide a general overview of radiation transport mechanisms in matter, beginning with a derivation of the Boltzmann radiation transport equation, and examining the various approximations possible. Focus on the single-energy Diffusion approximation will be examined in detail, as it relates to neutron diffusion nuclear reactors and optical photon diffusion. Review of photon diffusion in tissue will be discussed as it relates to tissue spectroscopy and imaging. Fundamental research papers in this field will be presented and reviewed, covering aspects of multiple scattering, Mie scattering, and scattering phase functions. Stochastic model-based approaches will be covered as well, such as the Monte Carlo model. Numerical approaches to solving these models will be introduced.

*Prerequisite:* ENGS 23 or equivalent

Instructor: Pogue

### **ENGS 169 Intermediate Biomedical Engineering**

Offered: 15S: 10

A graduate section of ENGS 57. Students taking the course for graduate credit will be expected to write a research proposal aimed at developing a specific surgical technology. Groups of 2-3 students will work together. The proposal will require an extensive literature review, a detailed proposal of research activities, alternative methods, and timeline, and a detailed budget and budget justification for meeting the research objectives. Weekly meetings will take place between the groups and Professor Halter to discuss progress. By the end of the term the groups are expected to have a complete proposal drafted. Enrollment is limited to 18 students. Not open to students who have taken ENGS 57.

*Prerequisite:* ENGS 23 and ENGS 56 or equivalent

Instructor: Halter

**ENGS 170 Neuroengineering****Offered:** 15W, 16W: 2A

This course will introduce students to currently available and emerging technologies for interfacing with the human brain. Students will study the fundamental principles, capabilities and limitations of a range of relevant technologies within the scope of noninvasive brain-computer interfaces, neural implants, neurostimulation, sensory substitution and neuroinformatics. The ethical and societal ramifications of these technologies will also be considered. Applications of neuroengineering technology in medicine will be emphasized such as the diagnosis and treatment of neurological diseases and neural rehabilitation.

*Prerequisite:* ENGS 22 and ENGS 56

Instructor: Diamond

**ENGS 171 Industrial Ecology****Offered:** 15W, 16W: 10

By studying the flow of materials and energy through industrial systems, industrial ecology identifies economic ways to lessen negative environmental impacts, chiefly by reducing pollution at the source, minimizing energy consumption, designing for the environment, and promoting sustainability. The objective of this course is to examine to what extent environmental concerns have already affected specific industries, and where additional progress can be made. With the emphasis on technology as a source of both problems and solutions, a broad spectrum of industrial activities is reviewed ranging from low-design high-volume to high-design low-volume products.

Students activities include a critical review of current literature, participation in class discussion, and a term project in design for the environment.

*Prerequisite:* ENGS 21 and ENGS 37

Instructor: Wegst

**ENGS 172 Climate Change and Engineering****Offered:** 15W: arrange

The current assessment by the Intergovernmental Panel on Climate Change (IPCC) of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) will be examined. The course will begin by scrutinizing the scientific basis of the assessment. Subsequently, regional and global impact projections will be examined. The technological options will be examined with respect to research and capitalization priorities, both corporate and governmental. Finally, the possibilities for novel governance structures based on a scientific understanding will be examined. Weekly critical presentations of the source material will be required. The course will culminate in the preparation, presentation, and refinement of a term paper of the student's choosing.

*Prerequisite:* Junior or senior standing in the Science Division; graduate standing in engineering or science; or permission

Instructor: Albert

### ENGG 173 Energy Utilization

Offered: 15W, 16W: 10A

Industrial societies are presently powered primarily by fossil fuels. Continuing to supply energy at the rate it is now used will be problematic, regardless of the mix of fossil fuels and alternatives that is used; yet western consumption patterns spreading through the rest of the world and other trends portend large increases in demand for energy services. Increased energy efficiency will be essential for meeting these challenges, both to reduce fossil-fuel consumption and to make significant reliance on alternatives feasible. Technical issues in efficient systems for energy utilization will be surveyed across major uses, with in-depth technical analysis of critical factors determining possible, practical, and economical efficiency improvements in both present technology and potential future developments. Areas addressed include lighting, motors and drive systems, heating, ventilation and air conditioning, transportation, appliances and electronics.

*Prerequisites: ENGS 22 and at least two of the following: ENGS 25, ENGS 32, ENGS 34, ENGS 44, ENGS 52, ENGS 76, ENGS 104, ENGS 125, ENGS 150, ENGS 155, ENGS 156, and ENGM 184, or permission. ENGS 25 is strongly recommended.*

Instructor: Sullivan

### ENGG 174 Energy Conversion

Offered: 14F, 15F: 11

This course will address the science and technology of converting key primary energy sources—fossil fuels, biomass, solar radiation, wind, and nuclear fission and fusion—into fuels, electricity, and usable heat. Each of these topics will be analyzed in a common framework including underlying fundamentals, constraints on cost and performance, opportunities and obstacles for improvement, and potential scale.

*Prerequisites: ENGS 22 and at least two of the following: ENGS 25, ENGS 32, ENGS 34, ENGS 36, ENGS 44, ENGS 52, ENGS 76, ENGS 104, ENGS 125, ENGS 150, ENGS 155, ENGS 156, and ENGM 184, or permission. ENGS 25 is strongly recommended.*

Instructor: Laser

### ENGS 175 Energy Systems

Offered: 15S, 16S: 2A

A consideration of energy futures and energy service supply chains at a systemic level. Dynamic development of demand and supply of primary energy sources and key energy carriers will be considered first assuming continuation of current trends, and then with changes to current trends in order to satisfy constraints such as limiting carbon emissions and changing resource availability. Integrated analysis of spatially-distributed time-variable energy systems will also be addressed, with examples including generation, storage, and distribution of electricity and production of energy from biomass.

*Prerequisites: ENGS 25, ENGS 51, either ENGG 173 or ENGG 174 or permission of the instructor*

Instructors: Lynd, Peterson

### ENGG 176 Design for Manufacturing

Not offered 2014–2015

Design for Manufacturing (DFM) is an analysis-supported design approach in which analytical models incorporating manufacturing input are used at the earliest stages of design in order to influence part and product design towards those design choices that can be produced more easily and more economically. DFM analysis addresses any aspect of the developing design of parts in which the issues of manufacturing are involved. The designed object is considered explicitly through its geometries and material selection and their impact on manufacturing costs. This course is intended primarily for students interested in mechanical, industrial, and manufacturing engineering, as well as for engineering design practitioners in industry. The course will emphasize those processes most often used in the mass production of consumer products and will include such processes as assembly, injection molding, die casting, stamping and forging.

*Prerequisite: ENGS 73 or permission of instructor*

### ENGG 177 Decision-Making under Risk and Uncertainty

Offered: 14F, 15F: W 3:00–4:50, Th 4:00–5:50

Making decisions under conditions of risk and uncertainty is a fundamental part of every engineer and manager's job, whether the situation involves product design, investment choice, regulatory compliance, or human health and safety. This course will provide students with both qualitative and quantitative tools for structuring problems, describing uncertainty, assessing risks, and reaching decisions, using a variety of case studies that are not always amenable to standard statistical analysis. Bayesian methods will be introduced, emphasizing the natural connections between probability, utility, and decision-making.

*Prerequisites: ENGS 27, ENGS 93, or comparable background in probabilistic reasoning*  
Instructor: Borsuk

### ENGM 178 Technology Assessment

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 14F, 15F: M, W 1:00–2:50

This project course is grounded in technology-focused areas and provides an opportunity for teams of students to conduct a thorough analysis of prevalent and emerging technologies in fields of critical interest such as health, energy, the environment, and other complex systems and then to recommend and justify actions for its further development. Technology in an assigned application field will be analyzed by each student team, along with emerging, complementary and competing technologies, leading to 1) findings of those impediments and incentives for its further development, 2) identification and quantification of the societal and/or commercial benefits achievable from further development, and 3) recommendations for action in research funding, product and market development, public policy, and the like, that would most rapidly achieve the identified societal and/or commercial benefits.

*No prerequisite*

Instructor: March

### **ENGM 179 Accounting**

Offered: 15W, 16W: M, Tu 8:30-10:00

Accounting is the accumulation, reporting, and analysis of a company's financial data. It is used by both external decision makers, such as creditors and investors, and internal decision makers, from product line managers to the board of directors. This course develops the basic concepts underlying corporate financial statements, such as overhead allocation and product costing. It also introduces tools used by both external and internal decision makers to analyze and use accounting information.

*No prerequisite*

Instructors: Sansing, Stocken

### **ENGM 180 Corporate Finance**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 15S, 16S: M, Tu 9:45–11:15

Issues of financial management important to the engineering manager. A review of the concepts of engineering economy, including time value of money, net present value, and choosing among investment alternatives. Discussion of global and national economic factors impacting the modern technology-driven corporation—such as exchange rates, competitiveness, cost of capital, money markets, and tax policies. Examination of the role of the financial organization in a corporation and its relationship to the engineering manager. Evaluating a balance sheet and an income statement; understanding the effect of mergers, acquisitions, leveraged buyouts, and venture capital on R&D organizations. Discussion of the financial aspects of engineering project management, including planning and budgeting, project costing, and cost vs. schedule vs. performance trade-offs. One or several additional topics, such as defense industry economics, impacts of deregulation, intellectual property law, and economic forecasting, will be selected for discussion.

*Prerequisite: ENGM 179 or permission of instructor*

Instructor: Lewellen

### **ENGM 181 Marketing**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 14F, 15F: W, Th 8:20–9:50

This course introduces the role of marketing within business firms. Case studies drawn from a wide variety of consumer and industrial products and services provide an opportunity for students to apply concepts and techniques developed in assigned readings. Specific topics include customer analysis, market research, market segmentation, distribution channel policy, product policy and strategy, pricing, advertising, and sales force management. The course stresses oral and written expression and makes use of several computer exercises, spreadsheet analysis, and management simulations.

*Prerequisite: Permission of instructor*

Instructor: Sharma

**ENGM 183 Operations Management**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 15S, 16S: M, Tu 11:45–1:15

This course provides an introduction to the concepts and analytic methods that are useful in understanding the management of a firm's operations. We will introduce job shops, assembly lines, and continuous processes. Other topics include operations strategy, aggregate planning, production scheduling, inventory control, and new manufacturing technologies and operating practices.

*Prerequisite: ENGS 93*

Instructor: Hall

**ENGM 184 Introduction to Optimization Methods**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 14F, 15F: 10A

An introduction to various methods of optimization and their use in problem solving. Students will learn to formulate and analyze optimization problems and apply optimization techniques in addition to learning the basic mathematical principles on which these techniques are based. Topic coverage includes linear, nonlinear, and dynamic programming, and combinatorial optimization.

*No prerequisite*

Instructor: K. Baker

**ENGM 185 Topics in Manufacturing Design and Processes**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 15S: T, Th 4:30–6:30

The course will consist of four main topics: 1) technical estimating, 2) design of experiments, 3) design for manufacturability, 4) statistical process control. We will review technical estimating (TE), a vital skill in today's rapidly changing industry. Illustrative and interesting examples will be used to hone TE techniques. Design of experiments (DOE) will be covered in detail using Montgomery's Design and Analysis of Experiments. Analysis of variance, model adequacy checking, factorial designs, blocking and confounding, regression models, nesting, and fractional factorial and Taguchi designs will be taught. Design for manufacturability (DFM) will be covered so that by the end of the course the student will know how to establish a successful DFM program to optimize and continuously improve designs and manufacturing processes. Cost estimating related to manufacturing processes will also be presented, followed by an overview of failure analysis techniques. The course will also introduce the basics of statistical process control, including the Shewhart Rules.

*Prerequisite: ENGS 93*

Instructor: Lasky

**ENGM 186 Technology Project Management**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 15W, 16W: W, Th 1:15–2:45

Project management focuses on planning and organizing as well as directing and controlling resources for a relatively short-term project effort which is established to meet specific goals and objectives. Project management is simultaneously behavioral, and quantitative, and systematic. The course covers topics in planning, scheduling and controlling projects such as in new product development, technology installation, and construction. This course is aimed at both business and engineering students and combines reading and case-oriented activities.

*Prerequisite: ENGM 184 or equivalent*

Instructor: March

### **ENGM 188 Law, Technology, and Entrepreneurship**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: 14F, 15F: W, F 8:20–9:50

Taking a good idea and turning it into a successful product and a profitable business poses a number of technical, managerial, and financial challenges. The solutions to many of the challenges of entrepreneurship in general, and to those of starting up a technologically based business in particular, are provided by the law. A grounding in the law of intellectual property, contractual transactions, business structures, debt and equity finance, and securities regulation, both in the U.S. and in an international context, will help inventors and entrepreneurs to manage this part of the process intelligently and with a high likelihood of success.

*No prerequisite*

Instructor: Goodenough

### **ENGM 189 Medical Device Development**

(Cannot be used to satisfy any A.B. degree requirements)

(This course carries .5 credit)

Offered: 14F, 15F: M, Tu 1:15–2:45

This course is an overview of existing medical devices and discusses methods for development, evaluation and approval of new medical devices. The course will cover both diagnostic and interventional devices, and cover clinical and pre-clinical testing issues, as well as a discussion of FDA approval processes, funding startups, and cost effectiveness analysis. The course will involve several case studies as examples. For projects, students will work in teams to analyze needs in the medical setting and come up with a plan for a new device, and analyze how best to develop it with a new startup. Two classes per week, 5 weeks total.

*Prerequisite: Graduate standing in engineering or business administration*

Instructor: Paulsen

### **ENGG 192 Independent or Group Study in Engineering Sciences**

(Cannot be used to satisfy any A.B. degree requirements. May not be used for term-length research or design projects.)

Offered: all terms: arrange

An independent study course in lieu of, or supplementary to, a 100-level course, as arranged with a faculty member. To be used in satisfaction of advanced degree requirements, requests for approval must be submitted to the Thayer School graduate program director no later than the end of the first week of classes in the term in which the course is to be taken. No more than one such course should be used in satisfaction of requirements for any degree. Proposed courses should include full syllabus, resources and student evaluation methods.



**ENGG 194 Ph.D. Oral Qualifier**

(Cannot be used to satisfy any A.B., B.E., M.E.M., or M.S. degree requirements)

**Offered:** arrange

The oral qualifying exam, a set of questions put forward by an oral examination committee to the candidate, normally takes place before or during the fifth term of the student's program, or, in exceptional circumstances, early in the sixth term. The exam is open to the faculty, but not to the general public.

The committee tests the candidate's knowledge of principles and methods underlying the field in which advanced work is to be performed. The exam covers material selected by the candidate's advisor in consultation with the examining committee, and includes coverage of mathematical techniques appropriate to the research area. The structure of the preparation for the exam is flexible.

The examination committee consists of 4 members: the chair plus 3 Dartmouth faculty examiners, with at least 2 of the examiners from Thayer School. A Thayer faculty member other than the student's advisor chairs the committee. This chair is assigned by the director of the M.S. and Ph.D. programs.

The examination committee gives the student a pass, fail, or conditional pass result. Students who fail may retake the oral examination—one time only—within the following 3 months. No third attempt is allowed.

**ENGG 195 Seminar on Science, Technology, and Society**

(Cannot be used to satisfy any A.B., B.E., M.E.M., or M.S. degree requirements)

**Offered:** 14F, 15F: arrange

Presentation and discussion of timely issues in scientific and technological development and its relation to society. Topics vary from year to year. Examples include transition for scientific developments to technological developments and impacts of technological development on various aspects of society; ethics, social issues, environmental concerns, and government policy; entrepreneurship, marketing, labor markets, quality, international competition, and legal liability. The group meets for lunch with the Jones Seminar speaker and later in the day attends the Jones Seminar. The students are expected to read the material submitted by the speaker and to have prepared questions for the lunch meeting. Discussion will be moderated by the instructor. The grade for this seminar will be based on attendance and participation in the discussions. Students are required to attend 5 of the 8 or 9 seminars that take place in a typical term.

*Prerequisite:* Ph.D. student standing

Instructor: Pogue

**ENGG 196 Seminar on Applied Science and Technology**

(Cannot be used to satisfy any A.B., B.E., M.E.M., or M.S. degree requirements)

**Offered:** 14F, 15W, 15S: arrange

Weekly seminar on timely topics in science and technology. The fall offering is devoted to issues involving scientific and technological development and its relation to society. Academic residence requirement for Ph.D. students is established by enrollment in ENGG 196 for a minimum of three terms (with three absences allowed).

*Prerequisite:* Ph.D. student standing

Instructor: Pogue

### **ENGG 197 Ph.D. Professional Workshops**

(Cannot be used to satisfy any A.B., B.E., M.E.M., or M.S. degree requirements)

Offered: 15W, 16W: arrange

A sequence of workshops on the preparation for professional life after the Ph.D. program, culminating in the completion of a curriculum vitae or resume, outline of possible jobs, and a competitive grant proposal. A major goal is for the student to design and write a grant for a technology startup program or for an academic research grant. Successful research and SBIR proposals are outlined and the processes for evaluating them are offered by research principal investigators, grant administration officials, and corporate representatives. Both academic CVs and industry resumes can be developed. Workshops include job search guides, management skills and research team management. Submitted student proposals and CVs are critiqued for improvement.

*Prerequisite: Ph.D. student standing*

Instructor: Pogue

### **ENGG 198 Research-In-Progress Workshop**

(Cannot be used to satisfy any A.B., B.E., M.E.M., or M.S. degree requirements)

Offered: 15W, 16W: arrange

Annual meeting of all doctoral candidates in residence with each candidate presenting in generally understandable terms his or her research progress over the past year.

*Prerequisite: Ph.D. student standing*

Instructor: Pogue

### **ENGG 199 Special Topics in Engineering Sciences**

(Cannot be used to satisfy any A.B. degree requirements)

Offered: all terms: arrange

A special topics lecture course in lieu of, or supplementary to, a 100-level course, as arranged by a faculty member to be used in satisfaction of advanced degree requirements. The course must be approved by the graduate programs committee in advance of the term in which it is offered. No more than two such courses should be used in satisfaction of requirements for any degree. To permit action prior to the term's end, requests for approval must be submitted to the graduate director no later than the eighth week of the term preceding the term in which the course is to be offered. Proposed courses should include full syllabus, resources, and student evaluation methods. Courses that have a 100-level prerequisite should use ENGG 299.

### **ENGS 200 Methods in Applied Mathematics II**

(Identical to PHYS 110)

Offered alternate years: 16W: arrange

Continuation of ENGS 100 with emphasis on variational calculus, integral equations, and asymptotic and perturbation methods for integrals and differential equations. Selected topics include functional differentiation, Hamilton's principle, Rayleigh-Ritz method, Fredholm and Volterra equations, integral transforms, Schmidt-Hilbert theory, asymptotic series, methods of steepest descent and stationary phase, boundary layer theory, WKB methods, and multiple-scale theory.

*Prerequisite: ENGS 100, or equivalent*

Instructor: Staff

**ENGS 202 Nonlinear Systems****Not offered 2014–2015**

The course provides basic tools for modeling, design, and stability analysis of nonlinear systems that arise in a wide range of engineering and scientific applications including robotics, autonomous vehicles, mechanical and aerospace systems, nonlinear oscillators, chaotic systems, population genetics, learning systems, and networked complex systems. There are fundamental differences between the behavior of linear and nonlinear systems. Lyapunov functions are powerful tools in dealing with design and stability analysis of nonlinear systems. After addressing the basic differences between linear and nonlinear systems, the course will primarily focus on normal forms of nonlinear systems and Lyapunov-based control design methods for a variety of applications with an emphasis on robotics, mechanical control systems, and particle systems in potential fields.

*Prerequisite: ENGS 100 and ENGS 145 or equivalents and familiarity with MATLAB*

**ENGS 205 Computational Methods for Partial Differential Equations II****Offered alternate years: 15S: 11**

Boundary Element and spectral methods are examined within the numerical analysis framework established in ENGS 105. The boundary element method is introduced in the context of linear elliptic problems arising in heat and mass transfer, solid mechanics, and electricity and magnetism. Coupling with domain integral methods (e.g. finite elements) is achieved through the natural boundary conditions. Extensions to nonlinear and time-dependent problems are explored. Spectral methods are introduced and their distinctive properties explored in the context of orthogonal bases for linear, time-invariant problems. Extension to nonlinear problems is discussed in the context of fluid mechanics applications. Harmonic decomposition of the time-domain is examined for nonlinear Helmholtz-type problems associated with EM and physical oceanography.

*Prerequisite: ENGS 105*

Instructor: Paulsen

**ENGG 210 Spectral Analysis**

*(Can be used by undergraduates for A.B. course count only)*

**Not offered 2014–2015**

An advanced treatment of digital signal processing for the analysis of time series. A study is made of parametric and nonparametric methods for spectral analysis. The course includes a review of probability theory, statistical inference, and the discrete Fourier Transform. Techniques are presented for the digital processing of random signals for the estimation of power spectra and coherency. Examples are taken from linear system theory and remote sensing using radar. Laboratory exercises will be assigned requiring the use of the computer.

*Prerequisite: ENGS 110*

**ENGG 212 Communications Theory**

*(Can be used by undergraduates for A.B. course count only)*

**Not offered 2014–2015**

An advanced treatment of communications system engineering with an emphasis on digital signal transmission. The course includes a review of probability theory, random processes, modulation, and signal detection. Consideration will be given to channel modeling, the design of optimum receivers, and the use of coding.

*Prerequisite: ENGS 110*

### **ENG 220 Electromagnetic Wave Theory**

Not offered 2014–2015

Continuation of ENG 120, with emphasis on fundamentals of propagation and radiation of electromagnetic waves and their interaction with material boundaries. Propagation in homogeneous and inhomogeneous media, including anisotropic media; reflection, transmission, guidance and resonance, radiation fields and antennas; diffraction theory; scattering.

*Prerequisite: ENG 100 and ENG 120 or permission of the instructor*

### **ENGG 230 Fatigue and Fracture**

(Can be used by undergraduates for A.B. course count only)

Not offered 2014–2015

A study of the fracture and fatigue behavior of a wide range of engineering materials (metals, ceramics, polymers, biological materials, and composites). Topics include work of fracture, fracture mechanics (linear elastic, elastic-plastic and plastic), fracture toughness measurements, crack stability, slow crack growth, environmentally assisted cracking, fatigue phenomenology, the Paris Law and derivatives, crack closure, residual stress effects, and random loading effects. These topics will be presented in the context of designing to avoid fracture and fatigue.

*Prerequisite: ENG 130 or permission of instructor*

### **ENGG 240 Kinematics and Dynamics of Machinery**

(Can be used by undergraduates for A.B. course count only)

Not offered 2014–2015

A study of kinematics, dynamics, and vibrations of mechanical components. Topics will include kinematic analysis and synthesis of mechanisms, with applications to linkages, cams, gears, etc.; dynamics of reciprocating and rotating machinery; and mechanical vibrations. Computer-aided design and analysis of kinematic and kinetic models.

*Prerequisite: ENG 72 (formerly ENG 140)*

### **ENG 250 Turbulence in Fluids**

Not offered 2014–2015

An introduction to the statistical theory of turbulence for students interested in research in turbulence or geophysical fluid dynamics. Topics to be covered include the statistical properties of turbulence; kinematics of homogeneous turbulence, phenomenological theories of turbulence; waves, instabilities, chaos and the transition to turbulence; analytic theories and the closure problem; diffusion of passive scalars; and convective transport.

*Prerequisite: ENG 150 or equivalent*

### **ENGG 261 Biomass Energy Systems**

(Can be used by undergraduates for A.B. course count only)

Offered alternate years: 15S: arrange

Biocommodity engineering is concerned with the biological production of large-scale, low unit value commodity products including fuels, chemicals, and organic materials. Intended primarily for advanced graduate students and drawing extensively from the literature, this course considers the emergence of biocommodity engineering as a coherent field of research and practice. Specific topics include feedstock and resource issues, the unit operations of biocommodity engineering—pretreatment, biological processing, catalytic processing, and separations—and the design of processes for biocommodity products.

*Prerequisite: ENG 157 and ENG 161 and permission of instructor*

Instructors: Lynd

**ENGG 296 Graduate Research (1 credit)****ENGG 297 Graduate Research (2 credits)****ENGG 298 Graduate Research (3 credits)****ENGG 299 Advanced Special Topics in Engineering Sciences**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** all terms: arrange

A special topics course in lieu of, or supplementary to, a 200-level course, as arranged by a faculty member, to be used in satisfaction of degree requirements. The course must be approved by the graduate programs committee in advance of the term in which it is offered. No more than one such course may be used in satisfaction of requirements for any degree. Requests for approval must be submitted to the program director no later than the eighth week of the term preceding the term in which the course is to be offered, to permit action prior to the term's end. Proposed courses should include full syllabus, resources and student evaluation methods. Courses that do not have a 100-level prerequisite should use ENGG 199.

**ENGG 300 Enterprise Experience Project**

**Offered:** all terms

Hands-on experience with existing enterprises can create a valuable training and enrichment experience for students in the Thayer graduate programs. For this course, you will propose and arrange a paid or unpaid internship in an existing enterprise (industry, government or other) in consultation with your faculty advisor prior to enrollment. Enrollment is concurrent with the internship and should be for a period of one quarter. At the end of the internship, you will make a presentation to the Thayer community that addresses the nature of the enterprise you were engaged in, the problem you were assigned, and the results and impact of your project. The purpose of the presentation is to share lessons learned from the experience with the Thayer community. The presentation will be accompanied by a short but complete written report. Neither the presentation nor report should contain confidential information of the enterprise. Internship proposals require approval of the faculty advisor. The course is graded on a credit/no credit basis by the faculty advisor after completion of the report. Enrollment is open to M.S. and Ph.D. students that have completed at least three (3) quarters of program residency. Students may enroll in the course more than once, but students holding F-1 visas should consult with the Office of Visa and Immigration Services (OVIS).

### ENGG 309 Topics in Computational Science

(Cannot be used to satisfy any A.B. degree requirements.)

Offered: arrange

Contemporary theory and practice in advanced scientific computation, organized by physical application area. Course comprises two 5-week modules, selected from the following:

**Computational Fluid Dynamics.** This module covers four basic contemporary issues: (i) the inherent nonlinearity of fluids; (ii) the mixed hyperbolic/elliptic nature of the differential equations governing fluid motion; (iii) the concomitant algorithmic complexity of their numerical treatment; and (iv) the size, i.e., the large number of degrees of freedom found in most realistic problems. Discussion of advection-dominated flows: physical and numerical properties; temporal and spatial discretization issues; method of characteristics, upwind-ing, Galerkin and Petrov-Galerkin methods; artificial viscosity. Navier-Stokes and shallow water equations in 2- and 3-D: mixed interpolation; primitive equation and higher-order formulation; staggered meshes; boundary conditions on pressure, transport and stress; radiation conditions. Frequency domain solution of hyperbolic problems: nonlinear generation of harmonics; truncation errors in iterative methods

*Prerequisites: ENGS 34 and ENGS 105, or equivalent*

Instructor: Staff

**Computational Solid Mechanics.** This module will deal with the development and application of finite element methods for solid mechanics problems. After a brief treatment of the theory of elasticity, the finite element equations for elastic solids will be developed using variational techniques. Applications in two- and three-dimensional static elasticity will be considered. Techniques will then be developed to analyze the following classes of problems; nonlinear material behavior, especially plasticity; plates and shells; problems involving contact between two bodies; and dynamic analysis of elastic bodies.

*Prerequisites: ENGS 33 and ENGS 105, or equivalent*

Instructor: Staff

**Computational Electromagnetics.** This module focuses on numerical solutions of the Maxwell equations. Emphasis will be placed on problem formulation and implementation issues. Examples will be selected from a broad spectrum of topics such as electromagnetic scattering, waveguides, microwave circuits and strip-lines, bioelectromagnetics. Development of software to solve representative problems will be required. It is anticipated that the student will be capable of reading and understanding the current computational electromagnetics literature upon completion of this course.

*Prerequisites: ENGS 105 and ENGS 120*

Instructor: Staff

### ENGG 310 Advanced Topics in Signals and Systems

(Cannot be used to satisfy any A.B. degree requirements)

Offered: arrange

Advanced study in signal processing and system theory. Possible topics include multi-input/multi-output systems, two-dimensional systems (image processing), modeling and identification, optimal filtering, and advanced optics. Readings in current research literature and student presentations.

*Prerequisites: Different for each topic; normally include ENGS 123 and ENGG 210 or equivalent, and permission of instructor*

Instructor: Hansen

**ENGG 312 Topics in Statistical Communication Theory**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** arrange

Advanced study in any of the following or other topics may be pursued: information theory, coding, noise, random signals, extraction of signals from noise, pattern recognition, and modulation theory. Normally offered in alternate years.

*Prerequisites:* ENGS 93, ENGS 110, and permission of instructor

Instructor: Cybenko

**ENGG 317 Topics in Digital Computer Design**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** arrange

Critical analysis of current literature in an emerging area of digital technology, such as multi-processor architecture, decentralized networks of small computers, bubble memories, ultra-fast arithmetic logic, specialized computers for digital filtering, etc. A term paper will be required.

*Prerequisites:* ENGS 116 and permission of instructor

Instructor: Cybenko

**ENGG 321 Introduction to Innovation****Offered:** F, W, and S: arrange

ENGG 321 provides students in the Ph.D. Program in Innovation with experience in the process of commercializing a new technology. During the fall (or winter) term, the students act as faculty assistants for ENGS 21 to provide a learning experience in oversight of various projects. During the winter term, students meet on a weekly basis to discuss a variety of reading assignments in innovation and enterprise building. During the spring term, students choose a technology to commercialize, typically from their own dissertation research efforts. During that term students develop a full enterprise plan for commercialization of the technology, including IP issues and strategy, applications, market forecasting and strategy, product development plans, a full multi-year monthly financial cost plan for all aspects of the enterprise, and a resource plan including personnel and funding. Students meet weekly and make installment presentations to their classmates and instructor for discussion and modification. Ad hoc discussion of related issues to running an enterprise, such as team building and personnel, infrastructure, funding options, whole product, and the “chasm” between invention and product, also takes place. The spring term is an intensive experience and students should reserve sufficient time for the course activity. At the end of the spring term students will present their enterprise plan to a review panel of internal and external seasoned entrepreneurs and an audience of IP Fellows for feedback and discussion.

*Prerequisites:* ENGM 188; ENGM 180 recommended; a proposal for research of a specific new technology must be developed and approved by the course faculty prior to the fall term. ENGG 197, taken in the winter term, is a co-requisite.

*NOTE:* Students in the Ph.D. Program in Innovation normally take this course during the third year of the program when their research is sufficiently advanced to have the prerequisite proposal for new technology. Ph.D. students not admitted to the Innovation program may request to enroll in this class in addition to their required courses. Because of the reduced frequency of meeting, credit is given for only one course, one-half for the fall term and one-half for the spring term.

Instructor: Fossum

### **ENGG 324 Microstrip Lines and Circuits**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** arrange

Analysis of transmission structures and circuit elements at microwave frequencies. Microwave network representation. Characterization and sensitivities of transmission structure. Discontinuities. Two-dimensional planar components. Models for microwave semiconductor devices. Microwave networks.

*Prerequisites:* ENGS 61, ENGS 105, ENGS 120, and permission of instructor

Instructor: Tremblay

### **ENGG 332 Topics in Plastic Flow and Fracture of Solids**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** arrange

Advanced study may be pursued on topics related to the microscopic aspects of the plastic flow and fracture of solids. The topics extend those introduced in ENGS 130 and ENGS 132 by providing an in-depth examination of the methods of strengthening, brittle and ductile fracture, fatigue, creep, and superplasticity. The emphasis is on the mechanisms underlying the phenomena. Readings in the literature will be assigned, and the student will be required to prepare a detailed term paper.

*Prerequisites:* ENGS 130, ENGS 132, and permission of instructor

Instructor: Frost

### **ENGG 339 Advanced Electron Microscopy**

(Cannot be used to satisfy any A.B. degree requirements)

**Offered:** arrange

Image formation and contrast are discussed for the transmission electron microscope, using both kinematical and dynamical theory. Image simulation methods are outlined and the information from a variety of diffraction methods, such as CBED, are described. Various analytical techniques such as electron energy loss spectroscopy and x-ray fluorescence, including advanced techniques such as ALCHEMI, are covered. Emphasis is placed on the applications, resolution, and theoretical and practical limitations of each technique. There are several laboratory sessions, each requiring a report.

*Prerequisite:* ENGS 133 or permission of instructor

Instructor: I. Baker

### **ENGG 365 Advanced Biomaterials**

(Cannot be used to satisfy any A.B. degree requirements.)

**Offered alternate years:** 16S: arrange

This course will focus on the interface between the host and implant with greater emphasis on the tissue reaction to metals, ceramics, polymers, bioceramics, and biopolymers than on the effect of the host environment on the materials. Ion release concerns, wear particle reactions, and the potential toxic properties of the salts of implant metals will be analyzed. The cells and cellular reactions available to the host will be evaluated in detail.

*Prerequisites:* ENGS 165 and permission of instructor

Instructor: Van Citters



**ENGG 367 Heat Transfer in Hyperthermia**

(Cannot be used to satisfy any A.B. requirements)

**Offered:** arrange

Review of coordinate systems, energy conservation equation, and temperature and heat-flux boundary conditions. Capillary blood perfusion as a distributed heat sink. Summary of distributed heat-flux sources associated with one or more of the following: internal and external radio-frequency, ultrasound, and microwave applicators. Surface cooling. Steady-state analytic and numerical solutions to practical problems in one and two dimensions. One or more of these advanced topics: transient responses, large blood vessels as discrete heat sinks, approximate solutions in three dimensions, lumped approximations to distributed systems.

*Prerequisites:* ENGS 23, ENGS 156, and permission of instructor

Instructor: Trembly

**ENGM 387 M.E.M. Professional Skills**

(Cannot be used to satisfy any A.B., B.E., M.S., or Ph.D. degree requirements)

**Offered:** 14F, 15F: 3A

This course develops professional skills required for professional success during and after the M.E.M. program. Skills acquired provide a basis for success in pursuing, securing and performing an internship and a post-graduation job. In a series of workshops, the course targets career self-assessment, ethics, interpersonal, and communication skills. Homework assignments provide practice and feedback for skills learned. ESL (English as a Second Language) support is offered as needed in the context of written and speaking activities of the course.

*No prerequisite*

Instructors: Staff

**ENGG 390 M.E.M. Project****Offered:** arrange

An individual engineering project to be completed during any term of the final year of an M.E.M. program. The project should define a practical need and propose a means to satisfy it, display an ability to conceive and evaluate solutions, describe appropriate analytical, experimental, and economic evaluations, and provide recommendations for further action. Projects will normally either have an industrial context or will be related to a specific design objective within a research program at Thayer School.

*Prerequisites:* ENGM 178 or permission of instructor

Instructor: Cushman-Roisin, March

## Management Courses (Tuck School of Business)

The following Tuck electives are available to M.E.M. students. All courses require permission from the instructor and prior approval of the M.E.M. program director. For a listing of Tuck management courses, see:  
[tuck.dartmouth.edu/mba/](http://tuck.dartmouth.edu/mba/)

### Corporate Valuation

Students will estimate cash flows, discount rates, and terminal values in order to establish intrinsic values for projects and firms using well-known valuation methods. In addition to traditional discounted cash flow (DCF) analysis, the course examines alternative valuation approaches such as real option valuation, relative valuation, and cross-border valuation. The course will explore valuation approaches in such classic settings as IPOs, mature cash flow businesses, LBOs, mergers & acquisitions, and project financing. The links between corporate valuation and corporate financial decisions regarding capital structure and corporate performance evaluation are also explored. The course will use a mixture of lectures, cases, projects, and guest speakers.

*Prerequisite: ENGM 180*

### Advanced Competitive Strategy

This course is designed to analyze the strategic lessons learned from the fields of military science, political science, international relations, and history, especially of the history of world empires from Ancient Rome to the British and even modern America. Applying these lessons to business, this course examines when and where to use guerilla versus traditional war fighting strategies, defensive versus offensive strategic postures, brinkmanship versus cooperative strategies, and revolutionary versus counterrevolutionary strategies. Part of the course is devoted to the use of portfolio strategy as a competitive weapon to create mutual assured destruction, to shift the balance of market power between competitors, and to create the conditions for profitability and stability by guiding the evolution of industry structure. To apply these concepts to business, the course develops visual tools such as price-quality analysis, stronghold analysis, know-how and smart-bombing analysis, as well as competitive pressure mapping and sphere-of-influence analysis. The course is designed to provide an alternative to traditional economic and strategic planning frameworks, sometimes presenting a contradictory viewpoint.

### Medical Care and the Corporation

Employer-sponsored healthcare plays a significant role in the US health system. From the standpoint of business leaders, healthcare plays a critical role in the viability and success of a business. This course will focus on the structure and dynamics of the healthcare system from the perspective of corporate leaders as both payors of care and trustees of healthcare organizations. Through the course, students will understand the importance of business executive's role in improving healthcare as a business and social imperative. The course is intended to 1) demonstrate how all corporate leaders can exercise judgment and control over expenditures for healthcare benefits while protecting the health of their employees 2) enhance the ability of all Tuck graduates to serve as Trustees of healthcare organizations, e.g., hospitals, physician group networks, insurers and purchasing collaboratives and 3) reinforce the applicability of core management concepts and techniques when serving in either of these capacities: employer/payor or healthcare organization trustee.

### Supply Chain Management

This course focuses on managing material and information outside the factory walls, including aspects of product design and configuration, forecasting, inventory planning for both material and finished goods, global sourcing decisions, distribution system design, channel management, logistics, and facility location. We will explore marketing distribution strategies, including order fulfillment for e-retailers and the impact of electronic commerce on both distribution and back-end supply chain processes.

*Prerequisite: ENGM 183*

### Private Equity Finance

The purpose of this course is to examine the financial perspective on decisions in entrepreneurial settings. While focusing on financial decisions, the course is integrative in looking at entrepreneurial financial decisions from the perspectives of the business opportunity, the goals of the participants, and the context, as well as looking at the “deal” and the resources employed. The course also offers a close examination of the investor’s role and the expanding institutional environment of private equity financing.

*Prerequisite: ENGM 180*

### Management of Service Operations

In this class we will develop both quantitative tools and qualitative models that will help us to manage service operations. The class focuses on four topics: (i) the operations/marketing interface, (ii) managing variability in services, (iii) demand and revenue management, and (iv) service quality improvement. The first two topics run throughout the mini-course. For topic (i), we will focus on the importance of aligning the design and management of services with the marketing strategy of the firm. For (ii), we will see that service firms experience the types of variability seen in manufacturing (variability in customer demand and service times), but are also faced with sources of variability that are unique to services, including customers’ expectations, subjective preferences, and their willingness or ability to participate in elements of the service process. This makes the management of variability particularly challenging, and important, in services. Concepts and tools in the mini-course will be applied to examples from health care, retail, car rental firms, airlines, and others.

*Prerequisite: ENGS 93*

### Marketing Research

This course is designed to expose students to the scope of marketing research and to the most frequently used marketing research techniques. The goal of the course is to make students knowledgeable users of marketing research information. The first part of the course considers the acquisition of data. Research design, sampling procedures, and questionnaire design are discussed in the context of both traditional and online market research. The second part of the course introduces students to multivariate data analysis techniques, including cross-tabulations, factor analysis, and conjoint analysis. The course uses readings, case studies, and hands-on business projects.

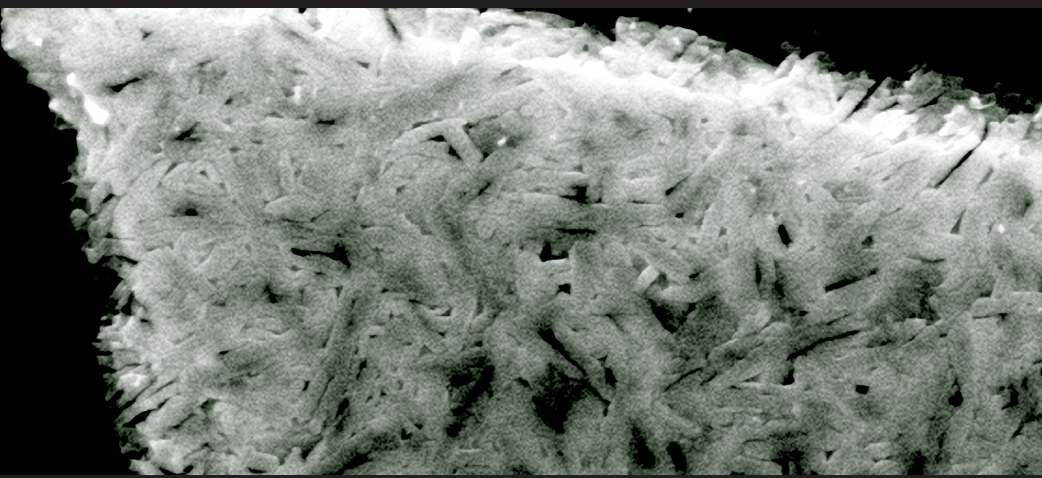
*Prerequisites: ENGS 93, ENGM 181*

### **Structure, Organization and Economics of the Health Care Industry**

(This is a full-term course)

Health care is a major area of interest for business leaders today and in the future. Health care represents the largest sector of the U.S. economy, with health care spending now at 16% of the gross domestic product and projected to be at 20% by 2015. Health care organizations, and corporations serving those organizations, are a major business sector offering significant career opportunities in management. Biotech research and development is one of the most dynamic areas of entrepreneurial and small business activity. Health care represents a major focus for investment banking and consulting. Health care benefits and financing are major issues of concern for all U.S. businesses. This course is designed to provide business leaders with a fundamental understanding of the health care industry and critical issues in health care today. It will provide an industry-wide view from the differing perspectives within the health care value chain, including providers, suppliers, payers and consumers. The course will examine the unique market dynamics among these players. It will introduce students to the structure, organization and financing of health care in relationship to business and the economy. This course is appropriate for students who are contemplating careers in companies serving the health care industry, such as consulting, private equity or banking, or who have an interest in careers in health care (pharmaceuticals, medical devices, biotech, or health delivery).

# Index



Tin monoxide (SnO) nanoneedles, imaged by scanning electron microscopy.  
Image courtesy of M.S. graduate Andrew Wong '12 Th'14, working in Professor Jifeng Liu's lab.

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# Directory

A complete directory of administration and staff is at:  
[engineering.dartmouth.edu/people/administration/](http://engineering.dartmouth.edu/people/administration/)

A password-protected photo directory of students, faculty, and staff is at:  
[engineering.dartmouth.edu/directory/](http://engineering.dartmouth.edu/directory/)

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The officers of Dartmouth College believe that the information contained in this Guide to Programs and Courses is accurate as of the date of publication (August 2014), and they know of no significant changes to be made in the near future. However, Dartmouth College and Thayer School of Engineering reserve the right to make such changes in their operations, programs, and activities as the Trustees, overseers, faculty, and officers consider appropriate and in the best interests of the Dartmouth community.

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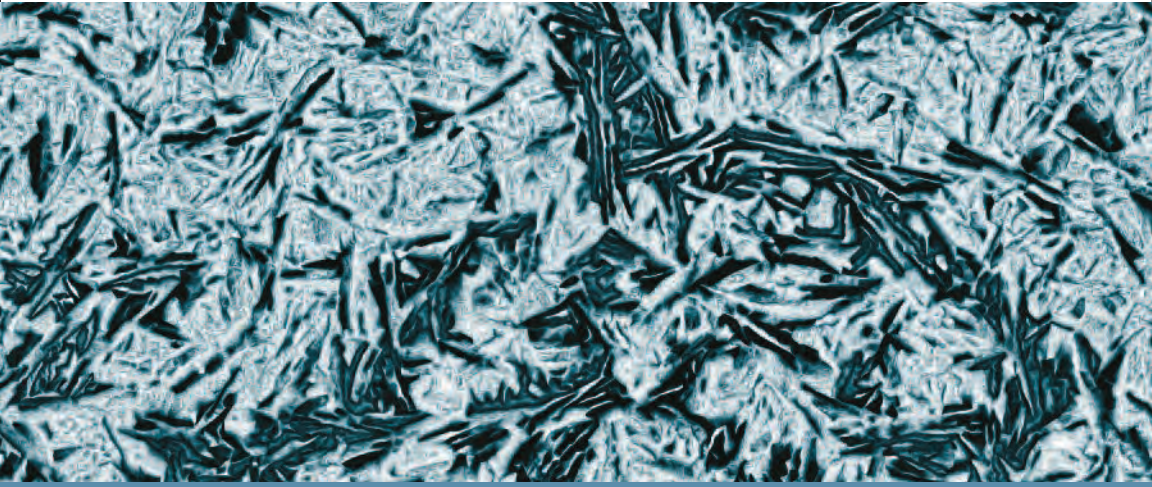
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ENGINEERING  
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