

# Department of Materials Science and Engineering

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Materials Science & Engineering (MSE) is an engineering discipline that applies the tools of basic and applied sciences and engineering to the manufacture and application of materials and devices. The four broad classes of Materials to which this paradigm is applied are metals, polymers, ceramics, and composites. Essentially every technology (historical, modern, and future) depends on materials development and innovation.

The overarching paradigm of MSE is to determine and to exploit the connection between processing, structure, and properties of materials to engineer materials that fit the performance criteria for specific applications, which are useful for the technological needs of our society. In addition to this product specific knowledge, MSE is concerned with the implications of materials production and their sustainable use on the environment and energy resources.

Graduates of the MSE department are pursuing careers in an expanding spectrum of companies, national laboratories, and universities. Their activities cover a wide range of materials related endeavors that include microelectronics, energy production and storage, biomedical applications, aerospace, information technology, nanotechnology, manufacturing and materials production. Many of our undergraduate alumni choose to attend graduate school; they are accepted into the top Materials graduate schools in the country.

The standard curriculum of the department provides fundamental training for all materials science and engineering areas ([http://www.cmu.edu/engineering/materials/undergraduate\\_program/curriculum/index.html](http://www.cmu.edu/engineering/materials/undergraduate_program/curriculum/index.html)). The core courses provide understanding and training on tools for working with the (atomic) structure of materials that governs their properties, the thermodynamic relationships that govern the stability of materials, and the rates at which changes take place in materials. Students complete their learning with a capstone design experience in the final year, which integrates their materials knowledge and training with engineering team skill development. To supplement the core course program, students may also participate in the current research programs of the faculty and conduct undergraduate research projects as part of their program of study.

While the core program is focused on the understanding of the internal or surface structure of materials in order to predict and engineer their properties, it is a flexible program that allows students to focus within a chosen material class, whether it is ceramics, semiconductors, metals, composites, magnetic or optical materials, bio-materials or polymers. The program also permits the option of cross concentration in the one or more of the areas of application such as electronic materials\*, engineering design\*, biomedical engineering\*, environmental engineering\*, manufacturing engineering\*, mechanical behavior of materials\*, biomedical and health engineering\*\*, and engineering and public policy\*\*, is also available. (\*= Designated Minor, \*\*= Double Major). Our curriculum is designed to provide a strong foundation in fundamental knowledge and skills that provide an excellent base for our graduates planning to continue on to graduate studies. For our graduates who seek employment in industry, the program provides the foundation on which a graduate can build his/her domain specific knowledge. For students that develop or seek opportunities in other disciplines after graduation, the MSE curriculum provides a modern liberal education combined with the engineering rigors, i.e. one that inculcates upon a thoughtful, problem-solving approach to professional life. It is thus the goal of our education to provide a global and modern education in Materials Science and Engineering to support our graduates during their careers in materials industries or as a foundation for further studies in any of the leading global institutions of graduate education.

## Accreditation

The MSE Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

## Educational Objectives

The faculty of the Department of Materials Science and Engineering, in consultation with students, alumni and other interested parties, has decided that the overarching objective of the MSE curriculum is to provide an education that enables our graduates to be productive and fulfilled professionals throughout their careers.

Specifically, our program will produce graduates who:

1. are successful in a top graduate school and/or in materials science & engineering positions;
2. excel in professionalism and leadership in modern interdisciplinary materials engineering practice, while accounting for the impact of their profession on an evolving society;
3. creatively advance our collective understanding of the principles of materials science and engineering and/or innovate the design of technological systems;
4. contribute effectively as an individual, team member, and/or a leader to achieve personal, group and institutional goals.

Based on these objectives, our program is focused to allow our students to be successful regardless of their future career choice.

## Student Outcomes

The Materials Science and Engineering Program has the following student outcomes to prepare graduates to attain the program educational objectives:

- A. An ability to apply a knowledge of mathematics, science and engineering
- B. An ability to design and conduct experiments, as well as to analyze and interpret data
- C. An ability to 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
- D. An ability to function on multidisciplinary teams
- E. An ability to identify, formulate, and solve engineering problems
- F. An understanding of professional and ethical responsibility
- G. An ability to communicate effectively
- H. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
  - I. A recognition of the need for, and ability to engage in life-long learning
  - J. A knowledge of contemporary issues
  - K. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

## Curriculum

Minimum units required for B.S. in Materials Science & Engineering 379

### Standard Program

#### Freshman Year

Fall		Units
21-120	Differential and Integral Calculus	10
27-100	Engineering the Materials of the Future *	12
99-101	Computing @ Carnegie Mellon	3
xx-xxx	General Education Course	9
33-141	Physics I for Engineering Students	12
		46

Spring		Units
21-122	Integration and Approximation	10
xx-xxx	Introductory Engineering Elective	12
33-142	Physics II for Engineering and Physics Students	12
09-101	Introduction to Experimental Chemistry	3
76-101	Interpretation and Argument	9
		46

#### Sophomore Year

Fall		Units
27-201	Structure of Materials	9
27-210	Materials Engineering Essentials	6
27-215	Thermodynamics of Materials	12
21-259	Calculus in Three Dimensions	9
09-105	Introduction to Modern Chemistry I **	10
15-110	Principles of Computing	10
or 15-112	Fundamentals of Programming and Computer Science	
39-210	Experiential Learning I	0
		56

Spring		Units
27-202	Defects in Materials	9
27-205	Introduction to Materials Characterization	3
27-216	Transport in Materials	9
27-217	Phase Relations and Diagrams	12
21-260	Differential Equations	9
39-220	Experiential Learning II	0
xx-xxx	General Education Course	9
		51

#### Junior Year

Fall		Units
27-301	Microstructure and Properties I	9
27-xxx	MSE Restricted Elective [1]	9
xx-xxx	Free Elective [1]	9
33-225	Quantum Physics and Structure of Matter or	9
or 09-217	Organic Chemistry I	
or 03-121	Modern Biology	
xx-xxx	General Education Course	9
39-310	Experiential Learning III	0
		45

Spring		Units
27-367	Selection and Performance of Materials	6
xx-xxx	General Education Course	9
27-xxx	MSE Restricted Elective [2]	9
27-xxx	MSE Restricted Elective [3]	9
xx-xxx	Free Elective [2]	9
36-220	Engineering Statistics and Quality Control	9
		51

#### Senior Year

Fall		Units
27-401	MSE Capstone Course I	6
27-xxx	MSE Restricted Elective [4]	9
xx-xxx	Free Elective [3]	9
xx-xxx	H&SS Elective [1]	9
xx-xxx	General Education Course	9
		42

Spring		Units
27-402	MSE Capstone Course II	6
27-xxx	MSE Approved Technical Elective	9
xx-xxx	Free Elective [4]	9
xx-xxx	Free Elective [5]	9
xx-xxx	H&SS Elective [2]	9
		42

\* The Materials in Engineering course 27-100 may also be taken in the spring semester, and must be taken before the end of the sophomore year (the H&SS Elective in the Sophomore Spring may be moved to later in the program to accommodate the 27-100 course).

\*\* These courses must be taken before the end of the sophomore year, but need not be taken in the same order or semester as listed above.

The recommended Physics sequence is 33-141 / 33-142 for Engineering students. However, 33-121 / 33-122 or 33-151 / 33-152 will also meet the CIT Physics requirement.

All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

## Notes on the Curriculum

### Academic Advising

All students in the MSE department are assigned an academic advisor. For questions regarding the curriculum, please contact Paige Houser, Wean Hall 3317.

### Quality Point Average

In addition to the College requirement of a minimum cumulative quality point average of 2.00 for all courses taken beyond the freshman year, the Department requires a quality point average of 2.00 or higher in courses taken in the MSE department. Students may repeat a course to achieve the QPA requirement. Only the higher grade will be used for this departmental calculation.

### MSE Restricted Electives

Each student in the Standard or Industrial Internship program must take at least 45 units of MSE restricted electives. In double major programs at least 36 units are required. The total number of units may be reached through any combination of the courses below.

All 27-3xx, 27-4xx, 27-5xx, 27-6xx (with the exception of 27-699) and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:

		Units
06-466	Experimental Polymer Science	9
06-609	Physical Chemistry of Macromolecules	9
06-619	Semiconductor Processing Technology	9
09-509	Physical Chemistry of Macromolecules	9
12-201	Geology	9
12-411	Project Management for Construction	9
12-631	Structural Design	12
18-310	Fundamentals of Semiconductor Devices	12
24-262	Stress Analysis	12
24-341	Manufacturing Sciences	9
33-341	Thermal Physics I	10
33-448	Introduction to Solid State Physics	9
42-411	Engineering Biomaterials	9

## Integrated B.S./M.S. Program

Undergraduates who excel academically have the unique opportunity to receive simultaneously or sequentially both B.S. and M.S. degrees from the department.

The primary purpose of the Integrated Master and Bachelor (IMB) Degree Program is to provide students with superior breadth and depth in technical material, which will better prepare them for careers in industry. Students interested in pursuing the IMB Degrees are encouraged to begin taking some of the required graduate courses before their last year. The MSE department offers two M.S. degrees: one in Materials Science and Engineering (MSE), a coursework degree, and one in Materials Science (MS), a coursework + research degree. The IMB Degree Program to obtain an M.S. in MSE (MS) degree normally requires two (three to four) additional full academic semesters of coursework (coursework + research) beyond the B.S. Degree Requirements (normally eight academic semesters). Experience has shown that students complete the IMB program in eight to ten full academic semesters after enrolling at CMU.

### Degree Requirements

IMB students can be enrolled in either the M.S. in MSE (coursework) or the M.S. in MS (coursework + research) degree programs, depending on their preference. Students must meet the requirements of either the M.S. in MSE or the M.S. in MS degree programs, as well as any specially stated rules below.

### Eligibility

The IMB Program is available to all undergraduates who maintain a cumulative QPA of 3.0 or better, including the freshman year and the years in which they are enrolled in the IMB. Exceptions can be made by the Department on the basis of other factors, including extenuating (e.g., medical) circumstances, improvement in grades, strong recommendation letters, etc.

Students become eligible to apply to the program during the spring semester of their junior year (5th semester), or the semester in which they accumulate 280 or more units, whichever is earlier.

### Enrollment

Students interested in the IMB program are not required to follow the formal application process for acceptance into the MSE graduate program. There is no requirement to provide a formal application, application fee, GRE scores, recommendation letters, official transcripts, or a statement of purpose. Interested students are encouraged request acceptance into the program by contacting the Department Head of MSE by email prior to the middle of the semester in which they become eligible.

### Requirements to Enroll as a Graduate Student

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MSE (coursework), then he or she must be a graduate student for at least one full-time 15-week academic semester (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MS (coursework + research), then he or she must be a graduate student for at least two full-time 15-week academic semesters (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

### Tuition Assistance

When a student is a full-time graduate student through the IMB program, the department is able to provide some tuition assistance through optional Teaching Assistantships.

### Additional Information

Once the student has been accepted, the student should meet with his or her IMB academic advisor(s) to determine a course schedule.

The student must indicate to the departmental program coordinator at which point they intend, if necessary, to register as a graduate student.

Once a student in the IMB program has completed all of the requirements for the B.S. degree, he or she should become a graduate student.

To determine the most appropriate time for an undergraduate student to become a graduate student, he or she should consult with Enrollment Services to understand how becoming a graduate student will affect financial aid.

## Faculty

CHRIS BETTINGER, Associate Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–.

MICHAEL BOCKSTALLER, Professor – Ph.D., Max-Planck Institute for Polymer Research; Carnegie Mellon, 2005–.

ITZHAQ COHEN-KARNI, Assistant Professor – Ph.D., Harvard University; Carnegie Mellon, 2013–.

ROBERT F. DAVIS, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–.

MARC DE GRAEF, Professor – Ph.D., Catholic University Leuven (Belgium); Carnegie Mellon, 1993–.

ADAM FEINBERG, Associate Professor – Ph.D., University of Florida; Carnegie Mellon, 2010–.

WARREN M. GARRISON, Professor – Ph.D., University of California at Berkeley; Carnegie Mellon, 1984–.

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–.

ELIZABETH A. HOLM, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2012–.

MOHAMMAD F. ISLAM, Research Professor of Materials Science and Engineering – Ph.D., Lehigh University; Carnegie Mellon, 2005–.

DAVID LANDIS, Executive Director of the Masters program in Energy Science, Technology and Policy – Ph.D., The Pennsylvania State University; Carnegie Mellon, 2010–.

DAVID E. LAUGHLIN, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–.

NOA MAROM, Assistant Professor – Ph.D., Weizmann Institute of Science; Carnegie Mellon, 2016–.

MICHAEL E. MCHENRY, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–.

YOOSUF PICARD, Associate Research Professor – Ph.D., University of Michigan; Carnegie Mellon, 2009–.

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LISA M. PORTER, Professor – Ph.D., North Carolina State; Carnegie Mellon, 1997–.

GREGORY S. ROHRER, Professor and Head – Ph.D., University of Pennsylvania; Carnegie Mellon, 1990–.

ANTHONY D. ROLLETT, Professor – Ph.D., Drexel University; Carnegie Mellon, 1995–.

PAUL A. SALVADOR, Professor – Ph.D., Northwestern University; Carnegie Mellon, 1999–.

MAREK SKOWRONSKI, Professor – Ph.D., Warsaw University; Carnegie Mellon, 1988–.

VINCENT SOKALSKI, Assistant Research Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–.

ELIAS TOWE, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–.

BRYAN A. WEBLER, Assistant Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–.

JAY WHITACRE, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2007–.

## Affiliated Faculty

AMIT ACHARYA, Professor, Civil and Environmental Engineering – Ph.D., University of Illinois, Urbana-Champaign; Carnegie Mellon, 2000–.

JAMES BAIN, Professor, Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1993–.

JACK BEUTH, Professor, Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–.

PHIL CAMPBELL, Research Professor, Institute for Complex Engineered Systems – Ph.D., The Pennsylvania State University; Carnegie Mellon, 2000–.

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KAUSHIK DAYAL, Associate Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–.

MAARTEN DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–.

RANDALL FEENSTRA, Professor, Physics – Ph.D., California Institute of Technology Carnegie Mellon; Carnegie Mellon, 1995–.

STEPHEN GAROFF, Professor, Physics – Ph.D., Harvard University; Carnegie Mellon, 1988–.

ANDREW GELLMAN, Lord Professor, Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–.

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TOMEK KOWALWESKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences; Carnegie Mellon, 2000–.

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SARA MAJETICH, Professor, Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–.

JONATHAN MALEN, Associate Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2009–.

KRZYSZTOF MATYJASZEWSKI, J.C. Warner Professor of Natural Sciences, Department of Chemistry and Materials Science and Engineering – Ph.D., Polytechnical University of #6d#, Poland; Carnegie Mellon, 1985–.

MEAGAN MAUTER, Assistant Professor, Civil & Environmental Engineering and Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2015–.

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ROBERT SEKERKA, University Professor, Physics, Mathematics and Materials Science – Ph.D., Harvard; Carnegie Mellon, 1969–.

ROBERT SUTER, Professor, Physics – Ph.D., Clark University; Carnegie Mellon, 1981–.

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NEWELL R. WASHBURN, Associate Professor of Chemistry, Biomedical Engineering and Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–.

LEE WEISS, Research Professor, ICES – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1983–.

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–.

JIAN-GANG ZHU, Professor, Electrical and Computer Engineering – Ph.D., University of California at San Diego.; Carnegie Mellon, 1997–.

## Emeriti Faculty

RICHARD J. FRUEHAN, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1981–.

THADDEUS B. MASSALSKI, Professor Emeritus of Physics, Materials Science and Engineering – Ph.D., D.Sc., University of Birmingham, England D.Sc. (h), University of Warsaw, Poland.; Carnegie Mellon, 1959–.

PAUL WYNBLATT, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1981–.