Department of Materials Science and Engineering

Gregory S. Rohrer, Head Office: Wean Hall 3327
http://materials.cmu.edu

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). 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:

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

### Freshman Year

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>21-120 Differential and Integral Calculus</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>27-100 Engineering the Materials of the Future*</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>99-101 Computing @ Carnegie Mellon</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>xx-xxx General Education Course</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>33-141 Physics I for Engineering Students</td>
<td>12</td>
</tr>
</tbody>
</table>

**Total Units:** 46

### Sophomore Year

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>27-201 Structure of Materials</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>27-210 Materials Engineering Essentials</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>27-215 Thermodynamics of Materials</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>21-259 Calculus in Three Dimensions</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>09-105 Introduction to Modern Chemistry I **</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>15-110 Principles of Computing</td>
<td>10</td>
</tr>
<tr>
<td>or</td>
<td>15-112 Fundamentals of Programming and Computer Science</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>39-210 Experiential Learning I</td>
<td>0</td>
</tr>
</tbody>
</table>

**Total Units:** 56

### Junior Year

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

**Total Units:** 45

### Senior Year

<table>
<thead>
<tr>
<th>Semester</th>
<th>Course</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>27-401 MSE Capstone Course I</td>
<td>12</td>
</tr>
</tbody>
</table>

**Total Units:** 51

### Minimum number of units required for degree:

- **379 Units**

*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 MSE 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.

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. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

### Industrial Intern Program

An industrial internship option (IIO - cooperative educational program) within the department offers an MSE student an opportunity to obtain valuable experience and insight from alternating periods in industry and on campus (beginning the spring after the sophomore year). The combination of learning while participating in an industrial environment with academic course work creates strongly motivated students and a personalized learning situation. Graduation with a B.S. degree occurs four and one-third calendar years after entering the university. Exceptionally able students may be admitted to a program leading to both the B.S. and M.S. degrees in five years. Students in the IIO program should consult with their faculty advisors before electing to participate in any of the designated minor programs.

Following the standard or industrial internship programs the graduate of the Department of Materials Science and Engineering is well prepared for leadership in our highly technological society which continues to demand more and more from the materials used in engineered systems. Many of our graduates elect to continue their education to the Master's and Doctoral Level in order to satisfy their need for advanced education in the discipline.

### Notes on the Curriculum

#### 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 27-5xx, 27-6xx* and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:

*with the exception of 27-699.

** Any materials based research project within CIT under an advisor of Courtesy Standing in MSE, at advisors discretion.
Teaching Assistantships. When a student is a full-time graduate student through the IMB program, for at least two full-time 15-week academic semesters (Fall or Spring) before in MS (coursework + research), then he or she must be a graduate student 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. Requirements to Enroll as a Graduate Student contacting the Department Head of MSE by email prior to the middle of the application process for acceptance into the MSE graduate program. There is Eligibility The IMB Program is available to all undergraduates who maintain a cumulative GPA 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 are enrolled in the IMB. 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. 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–. 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–. RICHARD J. FRUEHAN, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1981–. 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, Associate 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–. P. CHRIS PISTORIUS, Professor – Ph.D., University of Cambridge; Carnegie Mellon, 2008–. 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, 1992–. ANTHONY D. ROLLET, 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, 1999–. SUBRA SUKHSA, Professor and Head – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–. 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–.
KRIS NOEL DAHL, Associate Professor of Chemical Engineering and BioMedical Engineering and Materials Science and Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2006–.

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

MAARTEN DE BOER, Associate 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–.

REEJA JAYAN, Assistant Professor, Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–.

DAVID KINDERLEHRER, Professor, Mathematical Sciences – Ph.D., University of California, Berkeley; Carnegie Mellon, 1990–.

JOHN KITCHIN, Associate Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2006–.

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

SHAWN LITSTER, Associate Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–.

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

JONATHAN MALEN, – 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 Łódź, Poland; Carnegie Mellon, 1985–.

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

ALAN MCGAUGHEY, Associate Professor – Ph.D., University of Michigan; Carnegie Mellon, 2005–.

O. BURAK OZDOGANLAR, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–.

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–.

VENKAT VISWANATHAN, Assistant Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2013–.

LYNN WALKER, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–.

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

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–.