MATERIALS SCIENCE AND ENGINEERING

http://materials.jhu.edu/

Materials are essential to the construction of any engineering structure, from the smallest integrated circuit to the largest bridge. In almost every technology, the performance, reliability, or cost is determined by the materials used. As a result, the drive to develop new materials and processes (or to improve existing ones) makes materials science and engineering one of the most important and dynamic engineering disciplines.

The central theme of materials science and engineering is that the relationships among the structures, properties, processing, and performance of materials are crucial to their function in engineering structures. Materials scientists seek to understand these fundamental relationships and use this understanding to synthesize new materials or develop new processes for producing existing ones. Materials engineers design or select materials for particular applications and develop improved processing techniques. Since materials scientists and engineers must understand the properties of materials as well as their applications, the field is inherently interdisciplinary and draws on aspects of almost every other engineering discipline as well as physics, chemistry, and, most recently, biology. Because the field encompasses so many different areas, it is often categorized according to types of materials (metals, ceramics, polymers, and semiconductors) or to their applications (biomaterials, electronic materials, magnetic materials, or structural materials).

The department prepares students for successful careers in materials science and engineering, for advanced study in science or engineering, and for professional education in other fields. The goal of the undergraduate program is to provide a rigorous and comprehensive curriculum in materials science and engineering as well as in mathematics, basic sciences, humanities, and social sciences. Our low student-to-faculty ratio allows students close contact with faculty in both classroom and research environments, as well as with other students and researchers in the department. The student is encouraged to proceed at his or her own rate and to participate in interdisciplinary, interdepartmental, and interschool programs. In the tradition of Johns Hopkins, all of our undergraduate students participate in research, often beginning in their sophomore year, working closely with faculty and graduate students.

In recognition that biomaterials and nanotechnology represent two of the most rapidly developing areas of materials science and engineering, the Department of Materials Science and Engineering offers challenging specializations in biomaterials or nanotechnology within its undergraduate program.

The field of biomaterials is concerned with the science and engineering of materials in biology and medicine. Engineering materials are increasingly used in applications such as drug delivery and gene therapy, scaffolds for tissue engineering, replacement body parts, and biomedical and surgical devices. Biomaterials is an inherently interdisciplinary field that requires deep understanding of the properties of materials in general, and the interactions of materials with the biological environment. The Biomaterials concentration is designed to provide a firm grounding in the physics, chemistry, and biology of materials, as well as breadth in general engineering, mathematics, humanities, and social science. In addition, students are encouraged to gain hands-on experience in biomaterials research laboratories. The program seeks to educate students to reach the forefront of leadership in the field of biomaterials engineering. While the fundamental principles of materials science still apply, a complete understanding of biomaterials and their interactions with biological environments requires a greater degree of specialization than the standard undergraduate curriculum provides. In recognition of completion of the Biomaterials concentration, a student may elect to have his or her academic transcript annotated to indicate a specialty in biomaterials.

Nanotechnology advances the utilization of materials and devices with extremely small dimensions. Nanotechnology is a visionary field, as micro and nanostructured devices impact all fields of engineering, from microelectronics (smaller, faster computer chips) to mechanical engineering (micromotors and actuators) to civil engineering (“smart,” self-healing nanocomposite materials for buildings and bridges) to biomedical engineering (biosensors and tissue engineering). Materials science is central to nanotechnology because the properties of materials can change dramatically when things are made extremely small. This observation is not simply that we need to measure such properties or develop new processing tools to fabricate nanodevices. Rather, our vision is that the wide (and sometimes unexpected!) variety of phenomena associated with nanostructured materials allow us to envision radically new devices and applications that can only be made with nanostructured materials. The Nanotechnology concentration encompasses a curriculum designed to train students in the fundamental interdisciplinary principles of materials science including physics and chemistry, and also to expose students to the forefront of nanomaterials research through elective classes as well as research laboratories. Students in the Nanotechnology concentration will be well-prepared for successful careers in materials engineering across a wide range of disciplines. In recognition of completion of the Nanotechnology concentration, a student may elect to have his or her academic transcript annotated to indicate a specialty in nanotechnology.

The graduate curriculum provides students with a broad yet thorough grounding in the fundamentals of materials science and engineering. After completing the core curriculum, students pursuing master and Ph.D. degrees take advanced courses that will allow them to work at the forefront of knowledge in their chosen specialty. Those desiring to conduct original research and advance the frontiers of knowledge pursue a master’s essay and/or Ph.D. thesis. To this end, the department has an outstanding and wide-ranging research program, with particular emphasis on nanomaterials, thin films, metastable materials, biomaterials, computational materials science, and materials characterization.

Facilities

The teaching and research facilities of the Department of Materials Science and Engineering are located in Maryland Hall, Krieger Hall, and Croft Hall on the Homewood campus. The Department also administers the Materials Characterization and Processing Facility, which houses advanced tools for electron microscopy, X-ray diffraction, facilities for sample preparation, optical microscopy, and mechanical testing, as well as many other advanced materials tools for research and education. Individual research groups have established laboratories with advanced facilities for materials processing, nanotechnology, and materials characterization. Through collaboration with other departments and national laboratories, students and faculty also have access to a variety of other facilities necessary for world-class research.
Undergraduate Programs

Materials play a central role in the performance and reliability of virtually every technology and living organism. The central theme of materials science and engineering is that the relationships between the structure, properties, processing, and performance of materials are crucial to their function. Materials scientists seek to understand these fundamental relationships, synthesize new materials, develop improved processes for making materials, and understand the role of materials in the functioning of biological organisms. The wide range of problems addressed makes materials science one of the most highly interdisciplinary and dynamic engineering disciplines.

The Materials Science & Engineering faculty strives to maintain the Johns Hopkins University tradition of training a small number of students of the highest quality. We measure our success by the impact our graduates have on the scientific and engineering communities. Our program is designed to provide a solid foundation for future career development for students with diverse career aspirations.

Accreditation

Our BS program in Materials Science and Engineering is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org.

Program Educational Objectives:
The program has as its objectives that within 3 to 5 years, our graduates will:

- be engaged in advanced education, research, and development in materials science and engineering, including materials discovery and/or processing, and in any professional disciplines that benefit from an understanding of MSE.
- employ elements of the materials research process in their careers including the use of:
  - critical reasoning to identify fundamental issues and establish directions for investigation
  - creative processes to define specific plans for problem solution
  - analytical thought to interpret results and place them within a broader context.
- application of materials solutions to enhance or radically improve existing and future technology
- demonstrate ethical responsibility and an appreciation for the societal and global impact of their endeavors and maintaining their intellectual curiosity through lifelong learning.

Student Outcomes:

Students graduating with a B.S. in Materials Science and Engineering will have demonstrated:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Enrollments and Graduates:

<table>
<thead>
<tr>
<th>Academic Year</th>
<th>Total Enrollment</th>
<th>BS Degrees Awarded</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-2014</td>
<td>63</td>
<td>13</td>
</tr>
<tr>
<td>2014-2015</td>
<td>75</td>
<td>13</td>
</tr>
<tr>
<td>2015-2016</td>
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<td>21</td>
</tr>
<tr>
<td>2016-2017</td>
<td>60</td>
<td>12</td>
</tr>
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<td>2017-2018</td>
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<tr>
<td>2018-2019</td>
<td>73</td>
<td>20</td>
</tr>
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</table>

Requirements for the B.S. Degree

The Department of Materials Science and Engineering offers a program leading to the Bachelor of Science Degree. The B.S. for the Materials Science and Engineering degree program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org (http://www.abet.org). The student must meet the general university requirements for the chosen degree as well as the departmental requirements, and must complete the program approved by the student’s advisor.

An anticipated individual program of study designed to meet the university and department requirements for the B.S. degree, as well as to reflect the student’s interest, should be filed as early as possible during the student’s residence. The faculty advisor’s signature is required on all course registration and course change forms. As changes are made in the program, it shall be the student’s responsibility to see that a revised program is filed with the advisor. Each student must have an approved program on file no later than the semester before he/she expects to graduate.

General university requirements include (see also General Requirements for Departmental Majors for more information):

- Complete program of study outlined by track or concentration (standard track, biomaterials concentration, or nanotechnology concentration).
- Fulfill the university writing requirement; two writing intensive courses, at least 3 credits each
- Fulfill the distribution requirement: 18 credits of courses coded (H) or (S), comprised of 6 courses at least 3 credits each. See the Distribution tab in the Requirements for a Bachelor’s Degree (http://e-catalog.jhu.edu/undergrad-students/academic-policies/requirements-for-a-bachelors-degree) section for two exceptions to the rule that each H/S distribution course be at least 3 credits.
- Take a minimum of 126 credits.

To meet the course requirements for the B.S. degree in Materials Science and Engineering, the student must complete a minimum of 126 credits, distributed as follows:

<table>
<thead>
<tr>
<th>Course Classification</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Science Core Classes *</td>
<td>30</td>
</tr>
<tr>
<td>Upper Level Materials Science Classes *</td>
<td>12</td>
</tr>
<tr>
<td>Basic Sciences &amp; Engineering **</td>
<td>28</td>
</tr>
<tr>
<td>Mathematics **</td>
<td>20</td>
</tr>
<tr>
<td>Humanities (H) or (S) **</td>
<td>18</td>
</tr>
</tbody>
</table>
In addition to the degree program in Materials Science and Engineering, students may elect to complete specialized concentrations in biomaterials or nanotechnology. Whether a student chooses to pursue studies following the standard track, the Biomaterials concentration or the Nanotechnology concentration, the course work specified for the degree will provide a firm grounding in the principles of materials science and engineering.

Three B.S. Degree Options are Offered by the Department of Materials Science and Engineering

Standard Track
The Standard Track is intended for those students with general materials science interests. It permits the student to tailor the degree program to specific interests by allowing a broad range of choices for upper-level science and engineering electives.

Biomaterials Concentration
Biomaterials is an exciting and rapidly developing field. Engineered materials are increasingly used in medical applications (such as drug delivery, gene therapy, scaffolds for tissue engineering, replacement body parts, and biomedical and surgical devices) while an understanding of structure-property relationships in natural biomaterials may lead to improved interventions for a wide variety of diseases and injuries. Because it is highly interdisciplinary (involving elements of materials science, engineering, biology, chemistry and medicine), biomaterials as a discipline requires a deep understanding of the properties of materials in general, and the interactions of materials with the biological environment in particular.

The biomaterials concentration is designed to provide a broad basis in the fundamentals of materials science and engineering, as well as a particular emphasis on the principles and applications of biomaterials. While the fundamental principles of materials science still apply, a complete understanding of biomaterials and their interactions with biological environments requires a greater degree of specialization than the standard undergraduate curriculum provides. The biomaterials curriculum includes topics such as biomimetic materials, natural biomaterials, host responses to biomaterials, biocompatibility, and applications of biomaterials, particularly in tissue engineering, drug delivery, and medical devices and implants. Our goal is to train students who can apply these principles to the development of novel materials that benefit human health.

To receive commendation for completion of the Biomaterials concentration, the student must complete three electives, whose subject matter is some aspect of Biomaterials, Molecules and Cells as a Science & Engineering elective, a biomaterials laboratory course, and complete a biomaterials-related senior design project. Approval of electives must be made by a student’s academic advisor prior to taking the courses, and approval of the senior design project must be pre-approved by the senior design instructor.

Nanotechnology Concentration
Nanotechnology advances the utilization of materials and devices with extremely small dimensions. Nanotechnology is a visionary field, as micro- and nano-structured devices impact all fields of engineering, including microelectronics (smaller, faster computer chips), mechanical engineering (micromotors and actuators), civil engineering (“smart”, self-healing nanocomposite materials for buildings and bridges), and biomedical engineering (biosensors and tissue engineering).

Materials science is central to nanotechnology because the properties of materials can change dramatically when things are made extremely small. This observation is not simply that we need to measure such properties or develop new processing tools to fabricate nanodevices. Rather, our vision is that the wide (and sometimes unexpected) variety of phenomena associated with nanostructured materials allow us to envision radically new devices and applications that can only be made with nanostructured materials. The nanotechnology concentration encompasses a curriculum designed to train students in the fundamental interdisciplinary principles of materials science, including physics and chemistry, and also to expose students to the forefront of nanomaterials research through elective classes and research laboratories. In recognition of completion of the Nanotechnology concentration, a student may elect to have his or her academic transcript annotated to indicate a concentration in nanotechnology.

To receive commendation for completion of the Nanotechnology concentration, the student must complete three electives, whose subject matter is some aspect of Nanotechnology, a nanomaterials laboratory course, and complete a nanotechnology-related senior design project. Approval of electives must be made by a student’s academic advisor prior to taking the courses, and approval of the senior design project must be pre-approved by the senior design instructor.

Detailed Description of the B.S. Program
Materials Science Core Classes (30 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EN.510.311</td>
<td>Structure Of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.312</td>
<td>Thermodynamics/Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.313</td>
<td>Mechanical Properties of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.314</td>
<td>Electronic Properties of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.315</td>
<td>Physical Chemistry of Materials II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.316</td>
<td>Biomaterials I &amp; Biomaterials II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.428</td>
<td>Material Science Laboratory I &amp; EN.510.429</td>
<td>6</td>
</tr>
<tr>
<td>&amp; Materials Science Laboratory II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN.510.433</td>
<td>Senior Design Research &amp; EN.510.434</td>
<td>6</td>
</tr>
<tr>
<td>&amp; Senior Design/Research II or EN.510.438</td>
<td>&amp; Biomaterials Senior Design I &amp; EN.510.439</td>
<td></td>
</tr>
<tr>
<td>or EN.510.440 Nanomaterials Senior Design I &amp; EN.510.441</td>
<td>&amp; Biomaterials Senior Design II</td>
<td></td>
</tr>
<tr>
<td>or 510.445 MSE Design Team II &amp; 510.446 MSE Design Team II - Semester 2 or 510.447 MSE Design Team leader and 510.448 MSE Design Team Leader Semester 2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Upper Level materials science electives each 300 level or higher. 12

Basic Sciences and Engineering (28 credits)
Must be passed with a letter grade of C- or higher. Both 030.101 and 030.102 may substitute for 510.101. Students are required to take both semesters of Intro. Chem Lab.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.171.101</td>
<td>General Physics: Physical Science Major I</td>
<td>4</td>
</tr>
<tr>
<td>AS.171.102</td>
<td>General Physics: Physical Science Major II</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.111</td>
<td>General Physics Laboratory I</td>
<td>1</td>
</tr>
<tr>
<td>AS.173.112</td>
<td>General Physics Laboratory II</td>
<td>1</td>
</tr>
<tr>
<td>EN.510.101</td>
<td>Introduction to Materials Chemistry</td>
<td>3</td>
</tr>
<tr>
<td>AS.030.105</td>
<td>Introductory Chemistry Laboratory I</td>
<td>1</td>
</tr>
<tr>
<td>AS.030.106</td>
<td>Introductory Chemistry Laboratory II</td>
<td>1</td>
</tr>
<tr>
<td>AS.030.205</td>
<td>Introductory Organic Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>AS.030.225</td>
<td>Introductory Organic Chemistry Laboratory</td>
<td>3</td>
</tr>
<tr>
<td>EN.660.363</td>
<td>Leadership &amp; Management in Materials Science and Engineering</td>
<td>3</td>
</tr>
<tr>
<td>EN.500.114</td>
<td>Gateway Computing: Matlab</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Mathematics (20 credits)
Must be passed with a letter grade of C- or higher

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.109</td>
<td>Calculus II (For Physical Sciences and Engineering)</td>
<td>4</td>
</tr>
<tr>
<td>AS.173.111</td>
<td>General Physics Laboratory I</td>
<td>1</td>
</tr>
<tr>
<td>AS.110.201</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.302</td>
<td>Differential Equations and Applications</td>
<td>4</td>
</tr>
</tbody>
</table>

Humanities (H or S) (18 credits)
Must be passed with a letter grade of C- or higher (or S if the grade system is S/U). Introductory language courses, even if not with H or S designator, can substitute for H designated courses.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.110.109</td>
<td>Introduction to Languages</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.111</td>
<td>Introduction to Literature</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.112</td>
<td>Introduction to Visual Culture</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.113</td>
<td>Introduction to the Visual Arts</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.114</td>
<td>Introduction to Performance</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.115</td>
<td>Introduction to Cultural Studies</td>
<td>4</td>
</tr>
</tbody>
</table>

Science and Engineering Electives (9 credits)
Three courses of 200-level or above in engineering, natural sciences, or mathematics. At least one of the three electives must be from another department in the Whiting School of Engineering to ensure exposure to another engineering field. Must be passed with a letter grade of D or higher. For the Biomaterials concentration, one of the three electives must be 580.221: Molecules and Cells (4 credits) (students can substitute Cell Biology and Biochemistry for Molecules and Cells). For other students, a possible choice is 560.201 Statics and Mechanics of Materials (4 credits).

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>AS.110.201</td>
<td>Linear Algebra</td>
<td>4</td>
</tr>
<tr>
<td>AS.110.302</td>
<td>Differential Equations and Applications</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.101</td>
<td>Introductory Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.106</td>
<td>Introductory Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.107</td>
<td>Organic Chemistry</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.108</td>
<td>Physical Chemistry I</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.110</td>
<td>Physical Chemistry II</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.111</td>
<td>Quantum Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.112</td>
<td>Thermodynamics/Statistical Mechanics</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.113</td>
<td>Materials Science Topics</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.114</td>
<td>Materials Science Laboratory I</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.115</td>
<td>Materials Science Laboratory II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.116</td>
<td>Materials Science Laboratory III</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.117</td>
<td>Materials Science Laboratory IV</td>
<td>3</td>
</tr>
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</table>

Unrestricted Electives (9 credits)
Must be passed with a letter grade of D or higher. A student who has taken both 030.101 and 030.102 may count one of them toward one unrestricted elective.

Total Credits Required for Graduation, Standard Track: 126
- with Biomaterials Concentration: 127 Credits
- with Nanotechnology Concentration: 126 Credits

* Courses in other departments with an emphasis on the structure, properties, or processing of materials may be counted as materials science electives. A list of approved electives appears in the department’s Undergraduate Advising Manual (available from a student’s academic advisor). All 400-level or higher classes required in the Biomaterials and Nanotechnology concentrations will be counted toward satisfying the upper-level materials science electives requirement.

** Students are encouraged to also take the three credit EN.510.106 Foundations of Materials Science & Engineering.
*** For the Biomaterials concentration, EN.580.221 Molecules and Cells must be passed with a grade of C or higher.
**** A student who has taken both 030.101 and 030.102 may count one of them toward one unrestricted elective.

Sample Undergraduate Programs for Materials Science and Engineering

Standard Track
(For a student beginning with Calculus I)

Year 1

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS.030.101</td>
<td>Introductory Chemistry I</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.101</td>
<td>General Physics: Physical Science Major I</td>
<td>4</td>
</tr>
<tr>
<td>EN.510.106</td>
<td>Introductory Chemistry II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.107</td>
<td>Organic Chemistry</td>
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</tr>
<tr>
<td>EN.510.108</td>
<td>Physical Chemistry I</td>
<td>4</td>
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<td>EN.510.110</td>
<td>Physical Chemistry II</td>
<td>4</td>
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<tr>
<td>EN.510.111</td>
<td>Quantum Mechanics</td>
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<tr>
<td>EN.510.112</td>
<td>Thermodynamics/Statistical Mechanics</td>
<td>4</td>
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<tr>
<td>EN.510.113</td>
<td>Materials Science Topics</td>
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<td>EN.510.114</td>
<td>Materials Science Laboratory I</td>
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<td>EN.510.115</td>
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<tr>
<td>EN.510.116</td>
<td>Materials Science Laboratory III</td>
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<tr>
<td>EN.510.117</td>
<td>Materials Science Laboratory IV</td>
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Year 2

<table>
<thead>
<tr>
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<th>Title</th>
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<tr>
<td>EN.510.311</td>
<td>Structure Of Materials</td>
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<tr>
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<td>Introductory Organic Chemistry I</td>
<td>4</td>
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<td>Linear Algebra</td>
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<td>AS.110.302</td>
<td>Differential Equations and Applications</td>
<td>4</td>
</tr>
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<td>EN.510.312</td>
<td>Thermodynamics/ Materials</td>
<td>3</td>
</tr>
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<td>EN.510.313</td>
<td>Engineering</td>
<td>3</td>
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<tr>
<td>EN.510.314</td>
<td>Mechanical Properties of Materials</td>
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<td>EN.510.315</td>
<td>Electronic Properties of Materials</td>
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<td>EN.510.316</td>
<td>Materials Science Laboratory I</td>
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<tr>
<td>EN.510.317</td>
<td>Materials Science Laboratory II</td>
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<td>EN.510.318</td>
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Year 3

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<th>Course</th>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>EN.510.311</td>
<td>Structure Of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.312</td>
<td>Thermodynamics/ Materials</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.313</td>
<td>Engineering</td>
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<tr>
<td>EN.510.314</td>
<td>Mechanical Properties of Materials</td>
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<td>EN.510.315</td>
<td>Electronic Properties of Materials</td>
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<tr>
<td>EN.510.316</td>
<td>Materials Science Laboratory I</td>
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</tr>
<tr>
<td>EN.510.317</td>
<td>Materials Science Laboratory II</td>
<td>3</td>
</tr>
<tr>
<td>EN.510.318</td>
<td>Materials Science Laboratory III</td>
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</tr>
<tr>
<td>EN.510.319</td>
<td>Materials Science Laboratory IV</td>
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### Materials Science and Engineering

<table>
<thead>
<tr>
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<th>Course Title</th>
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<tbody>
<tr>
<td>EN.510.428</td>
<td>Material Science Laboratory I</td>
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<td>3</td>
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</tr>
<tr>
<td>EN.660.363</td>
<td>Leadership Management in Materials Science and Engineering</td>
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<tr>
<td>Math/Sci/Eng elective</td>
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**Year 4**

<table>
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<tbody>
<tr>
<td>EN.510.433</td>
<td>Senior Design Research</td>
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<td>510.4## - MSE elective</td>
<td>3 510.4## - MSE elective</td>
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<tr>
<td>510.4## - MSE elective</td>
<td>3 510.4## - MSE elective</td>
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<td>H/S elective</td>
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**Biomaterials Concentration**

(For a student beginning with Calculus I)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Fall Credits</th>
<th>Spring Credits</th>
<th>Total Credits</th>
</tr>
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<tbody>
<tr>
<td>AS.030.101</td>
<td>Introductory Chemistry I</td>
<td>3</td>
<td>3</td>
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<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
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<tr>
<td>AS.030.105</td>
<td>Introductory Chemistry Laboratory I</td>
<td>1</td>
<td>AS.171.102</td>
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<tr>
<td>AS.171.101</td>
<td>General Physics: Physical Science Major I</td>
<td>4</td>
<td>AS.173.112</td>
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<td>AS.173.111</td>
<td>General Physics Laboratory I</td>
<td>1</td>
<td>AS.110.109</td>
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<tr>
<td>EN.510.106</td>
<td>Foundations of Materials Science Engineering</td>
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<td>EN.500.114</td>
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**Year 3**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Fall Credits</th>
<th>Spring Credits</th>
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<tbody>
<tr>
<td>EN.510.315</td>
<td>Physical Chemistry of Materials II</td>
<td>3</td>
<td>3</td>
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<tr>
<td>EN.510.313</td>
<td>Mechanical Properties of Materials</td>
<td>3</td>
<td>3</td>
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</tr>
<tr>
<td>EN.510.428</td>
<td>Material Science Laboratory I</td>
<td>3</td>
<td>3</td>
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<tr>
<td>EN.660.363</td>
<td>Leadership Management in Materials Science and Engineering</td>
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<td>Math/Sci/Eng elective</td>
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**Nanotechnology Concentration**

(For a student beginning with Calculus I)

<table>
<thead>
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<th>Course Code</th>
<th>Course Title</th>
<th>Fall Credits</th>
<th>Spring Credits</th>
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<tr>
<td>AS.030.101</td>
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<td>3</td>
<td>3</td>
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<tr>
<td>AS.110.108</td>
<td>Calculus I</td>
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<tr>
<td>AS.030.105</td>
<td>Introductory Chemistry Laboratory I</td>
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<td>AS.171.102</td>
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**Total Credits:** 126

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**Total Credits:** 127

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**Total Credits:** 127
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<thead>
<tr>
<th>Year 2</th>
<th>Credits</th>
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<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EN.510.311 Structure Of Materials</td>
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<td>EN.510.312 Thermodynamics/ Materials</td>
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<tr>
<td>AS.030.205 Introductory Organic Chemistry I</td>
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<td>EN.510.316 Biomaterials I</td>
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<td>AS.110.202 Calculus III</td>
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<tr>
<td>H/S elective</td>
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<td>EN.553.291 Linear Algebra and Differential Equations</td>
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<tr>
<td>EN.560.201 Statics Mechanics of Materials</td>
<td>3</td>
<td>EN.553.310 Probability Statistics</td>
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### Year 3

<table>
<thead>
<tr>
<th>Credits</th>
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<th>Spring</th>
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<tbody>
<tr>
<td>EN.510.315 Physical Chemistry of Materials II</td>
<td>3</td>
<td>EN.510.314 Electronic Properties of Materials</td>
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<tr>
<td>EN.510.313 Mechanical Properties of Materials</td>
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<td>EN.510.429 Materials Science Laboratory II</td>
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<td>EN.660.363 Leadership Management in Materials Science and Engineering</td>
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### Year 4

<table>
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<tbody>
<tr>
<td>EN.510.440 Nanomaterials Senior Design I</td>
<td>3</td>
<td>EN.510.441 Nanomaterials Senior Design II</td>
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<td>510.4## - MSE Elective (e.g. Nanomaterials Lab)</td>
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<td>510.4## - MSE Elective (e.g. Micro Nano Materials &amp; Devices)</td>
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<tr>
<td>510.4## - MSE Elective (e.g. Materials Characterization)</td>
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<td>510.4## - MSE Elective (e.g. Nanoparticles)</td>
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<tr>
<td>Unrestricted elective</td>
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<td>H/S Elective</td>
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</table>

### Financial Aid

Information about scholarships and other sources of financial assistance for undergraduates is available from Student Financial Services (http://pages.jh.edu/~finaid). In addition, the faculty employs a number of undergraduates as laboratory assistants to help with various aspects of their individual research programs.

### Graduate Programs

The Department of Materials Science and Engineering (DMSE) offers three graduate degrees: the Ph.D. (Doctor of Philosophy), the M.S.E. (Master of Science in Engineering), and the M.M.S.E. (Master of Materials Science and Engineering). The Ph.D. and the M.S.E. can be completed on either a full-time or part-time basis (with advanced approval from the program). Financial aid is available only for students admitted to the full-time Ph.D. program. The M.S.E. degree may be completed either with or without an essay, as described below.

Hopkins undergraduate students are encouraged to complete both the B.S. degree and the M.S.E. degree in a total of five years. This five-year, dual degree option offers additional preparation for the pursuit of Ph.D. programs and careers in materials science and engineering. Students are encouraged to consult their undergraduate advisors to gain information on M.S.E. programs at Hopkins, as well as third- and fourth-year course selections best suited to the pursuit of the M.S.E. degree.

The M.M.S.E. is a terminal master’s degree offered through Johns Hopkins Engineering for Professionals (EP) of the Whiting School of Engineering. The degree program consists of 10 courses offered primarily in the evening. Students interested in this program should apply through the EP Office, 410.516.2300 or [www.ep.jhu.edu](http://www.ep.jhu.edu).

### Admission

To be admitted to graduate study in the Department of Materials Science and Engineering, students must submit credentials sufficient to convince the faculty that they have the potential to successfully complete the program requirements. Under the new GRE test, applicants should take the General Test package containing the Mathematical Reasoning test.

Hopkins undergraduate students who plan to pursue a M.S.E. degree in their fifth year are encouraged to submit an application early in their fourth year of study.

A graduate student pursuing a Ph.D. degree with the Department of Materials Science and Engineering who is funded by the department as a teaching assistant or research assistant may not enroll simultaneously in a master’s program in another department, unless he or she receives written approval from his or her advisor, the DMSE Graduate Program Committee, and the department chairman.

### Advising and Review of Student Performance

Each graduate student will normally have one or more faculty advisors. Students who are entering the M.S.E. program and plan to pursue a degree without an essay will be assigned an academic advisor. Students who are entering the Ph.D. program will be advised by their research advisor. Students with
a research advisor in another department will be assigned an internal academic advisor from among the full-time faculty in the department. Student progress will be assessed regularly by the faculty advisor(s) and the Graduate Program Committee. Students are expected to remain in regular communication with their faculty advisor(s).

Each student's progress will be reviewed annually by the Graduate Program Committee, in consultation with the student's advisor(s). To assist in this evaluation, students are required to submit a form (available from the academic program coordinator) detailing progress toward completion of the degree requirements. This form must be signed by the student's advisor(s) and filed with the Graduate Program Committee each year. The department must be convinced that all academic requirements have been satisfied by the candidate before a recommendation to confer a graduate degree is passed on to the University Graduate Board.

Grade requirements for graduate course work differ according to the degree program, as described below. All graduate students are required to maintain an overall grade point average (GPA) of 3.0 or higher; failure to do so will ordinarily be cause for dismissal from the program. Independent research courses will not be counted toward completion of course requirements.

The department believes that teaching experience is important to professional growth; therefore, a student may be required to serve as a teaching assistant during his or her academic career.

**Fulltime credit enrollment requirement for WSE graduate students:**
- All WSE Graduate Students must be enrolled in at least 9 credits to maintain fulltime status (in fall/spring semesters).
- Typically, fulltime WSE PhD students will be enrolled in a combination of WSE classes and/or research for a total of 20 WSE credits per semester (fall/spring).
- Typically, fulltime WSE Masters students will be enrolled in a combination of classes and/or research for a total of 9-10 credits a semester (fall/spring).

**Requirements for the M.S.E. Degree with Essay**

(8 courses)

The degree of Master of Science in Engineering (M.S.E.) with Essay is awarded subject to the recommendation of the student's advisor and departmental approval, based on satisfactory completion of the following requirements:

Academic Ethics (EN.500.603) and:

Three core courses in Materials Science and Engineering

- EN.510.601 Structure Of Materials 3
- EN.510.602 Thermodynamics Of Materials 3
- EN.510.603 Phase Transformations of Materials 3

* Two 600-level or higher and three 400-level or higher electives in materials science and engineering or related fields subject to the following rules:
  - Each elective must be worth at least three credits. Multiple courses that add up to three credits may be used in place of one three-credit course with approval from the Master's Degree Committee.
  - Up to two of the elective courses may be taken from within the Engineering for Professionals (EP) part-time program.
  - Up to two of the electives may be business courses.
  - Any elective taken from outside the department (including all EP courses) requires prior approval of the Master's Degree Committee. The Master's Degree Committee will determine the appropriate number of credits for any elective taken outside the Whiting School of Engineering.
  - With approval of the Master's Degree Committee, the student can transfer up to two graduate courses from another institution. Students desiring such credit must make the request in writing to the Master's Degree Committee by the end of the first semester after matriculation. This request must include a description of the course, a course syllabus, and documentation of the grade received. Please note that transfer coursework grades do not count towards calculation of the GPA.
  - Responsible Conduct of Research training (AS.360.624 or AS.360.625) in accordance with the Whiting School of Engineering policy. Details about this requirement, including the criteria for determining whether the online or in-person course must be taken, are provided in the description of the policy.
  - Training on academic ethics in accordance with the Whiting School of Engineering policy. This requirement can be satisfied by passing EN.500.603 (Academic Ethics).
  - A grade of C or better must be achieved in each course to obtain credit.
  - A overall grade point average of 3.0 must be maintained, and a grade point average of a 3.0 is required to earn the degree at the end of the program.
  - Attendance is required at the weekly Department of Materials Science and Engineering Seminar.

** Admission to the M.S.E. program is through the standard graduate admissions process. The typical duration of the program is 21 months. The student's transcript will reflect a "Master of Science in Engineering with Essay." There is an option to apply for the opportunity to complete an internship/co-op with an essay ([http://e-catalog.jhu.edu/departments-program-requirements-and-courses/engineering/materials-science-engineering/Master%20of%20Science%20and%20Engineering%20students%20looking%20for%20training%20and%20experience%20outside%20the%20classroom%20should%20consider%20our%20Masters%20Cooperative%20(Co-Op)%20Education%20program.%20In%20addition%20to%20the%20academic%20cooperative%20training%20this%20program%20places%20students%20in%20a%20company%20for%20six%20months%20where%20they%20are%20assigned%20to%20a%20specified%20research%20project.%20Students%20are%20required%20to%20complete%20an%20internship/co-op%20with%20an%20essay](http://e-catalog.jhu.edu/departments-program-requirements-and-courses/engineering/materials-science-engineering/Master%20of%20Science%20and%20Engineering%20students%20looking%20for%20training%20and%20experience%20outside%20the%20classroom%20should%20consider%20our%20Masters%20Cooperative%20(Co-Op)%20Education%20program.%20In%20addition%20to%20the%20academic%20cooperative%20training%20this%20program%20places%20students%20in%20a%20company%20for%20six%20months%20where%20they%20are%20assigned%20to%20a%20specified%20research%20project.%20Students%20are%20required%20to%20complete%20an%20internship/co-op%20with%20an%20essay)**
Admission to the M.S.E. program is through the standard graduate admissions process. The typical duration of the program is 12 months. The student's transcript will reflect a "Master of Science in Engineering."

**Requirements for the Ph.D. degree**

To receive the Ph.D. degree, the candidate must fulfill the requirements below. The department must be satisfied that all academic requirements have been satisfied by the candidate before a recommendation will be made to the University Graduate Board to confer the Ph.D. degree.

1. **Successful completion of four required courses in materials science and engineering.**

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<td>EN.510.601</td>
<td>Structure Of Materials</td>
<td>3</td>
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<td>EN.510.602</td>
<td>Thermodynamics Of Materials</td>
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<td>EN.510.603</td>
<td>Phase Transformations of Materials</td>
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<tr>
<td>EN.510.615</td>
<td>Physical Properties of Materials</td>
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Each of the four required courses must be passed with a letter grade of B- or higher. If a student receives a grade of C+ or lower in a required course, the student may re-take the course once to achieve a grade of B- or higher. Receipt of grades of C+ or lower in two or more required courses will ordinarily be cause for dismissal from the program without the opportunity to re-take those courses.

In addition, the student must maintain an overall GPA of 3.0 or better in the four required courses. If the student's GPA falls below 3.0, the student must re-take one or more of the required courses and earn higher grade(s). Upon doing so the prior grade(s) in those course(s) are replaced and not counted toward the GPA.
The four required courses must be successfully completed (meeting the grade and GPA requirements above) no later than the start of the student’s third year after matriculation; failure to do so will result in dismissal from the program. Exception: A student who fails to meet the requirements above due to a low grade in a single required course, and who has not had an opportunity to re-take that course during the first two years, will be permitted to re-take that one course in the third year.

Students who have completed prior graduate-level coursework similar to EN.510.601 Structure Of Materials, EN.510.602 Thermodynamics Of Materials or EN.510.603 Phase Transformations of Materials may petition the Doctoral Program Committee to waive one of these required courses. Alternatively, students with undergraduate degrees in Materials Science may petition the Doctoral Program Committee to waive the Physical Properties course. However, only one of the four required courses can be waived. If approved, the course that has been waived will not be counted toward calculation of the GPA as described above. Written requests for such waivers must be submitted to the Doctoral Program Committee no later than the end of the first semester after matriculation. Please note that transfer coursework grades do not count towards calculation of the GPA.

2. Successful completion of three advanced (600-level or higher) elective courses in materials science and engineering or a related field.

Elective courses must be completed with a grade of C or higher, but there is no cumulative GPA requirement. A list of approved electives is available from the Academic Program Coordinator. Students wishing to use a course not on this list must submit a request to the Doctoral Program Committee no later than the end of the first week of the semester in which the course is taken.

Graduate research (EN.510.807–EN.510.808), part-time graduate courses (from Engineering for Professionals in WSE or Advanced Academic Programs in KSAS), and seminars (courses with less than three contact hours per week) will not be counted toward completion of PhD course requirements. Undergraduate courses (400-level or lower) will not be counted unless they are cross-listed as graduate level, 600 or higher. Independent study courses may be used with prior approval of the Doctoral Program Committee.

Students who have completed prior graduate-level coursework may petition the Doctoral Program Committee to waive one of the required elective courses. Written requests for such waivers must be submitted to the Doctoral Program Committee no later than the end of the first semester after matriculation.

In some cases, an advisor may require a student to complete additional coursework, beyond the four required courses and three electives described above.

3. Attendance is required at the weekly Department of Materials Science and Engineering Seminar

4. Coursework required by Whiting School of Engineering policy. These include the following:
   a.) Responsible Conduct of Research training (AS.360.624 or AS.360.625) in accordance with Whiting School of Engineering policy. Details about this requirement, including the criteria for determining whether the online or in-person course must be taken, are provided in the description of the policy (https://engineering.jhu.edu/wse-research/resources-policies-forms/responsible-conduct-of-research).
   b.) Training on academic ethics in accordance with Whiting School of Engineering policy (https://engineering.jhu.edu/graduate-studies/academic-policies-procedures-graduate). This requirement can be satisfied by passing EN.500.603 (Academic Ethics).

5. Teaching Assistant Requirement: Students in their second year in the department will be required to act as teaching assistant for two courses.

6. Successful completion of a comprehensive oral examination covering fundamentals of materials science and engineering. The comprehensive examination tests knowledge in each of the subjects listed below:

   Structure of Materials
   Thermodynamics of Materials
   Phase Transformations in Materials

   In each of the three subject areas, students may be asked questions related to the properties of materials. The depth of required knowledge regarding properties of materials will match the level of knowledge presented in the Physical Properties of Materials class.

   Successful completion of the comprehensive exam requires satisfactory performance on all areas tested; there are no partial or conditional passes.

   The comprehensive exam is offered semiannually, usually immediately prior to the fall and spring semesters. A student who fails the exam on the first try may make a second attempt, but the exam must be successfully completed no later than the start of the third year following matriculation. Failure to do so will result in dismissal from the program.

7. A proposal for a research project to form the basis of the candidate’s dissertation.

   Each student must write a thesis proposal and present it orally at a public seminar no later than the end of the sixth semester following matriculation. The written dissertation proposal must be submitted to the department no later than two weeks prior to the scheduled date of the oral presentation. The public seminar will be followed by a closed session with a committee consisting of the research advisor and two other faculty members (to be selected in consultation with the advisor). During the closed session, the committee members will ask questions about and provide comments on the proposed plan of research. The thesis proposal is also an examination, with the committee testing the candidate’s depth of knowledge in his/her area of specialization (and not only on the proposed research). Students who do not successfully complete the dissertation proposal requirement by the end of the sixth semester following matriculation will be placed on probation, with a specified time limit (ordinarily no more than six months) within which to complete this requirement and be removed from probation. Students on probation who do not complete the dissertation proposal requirement within the specified time limit will be dismissed from the program.

8. Completion of an original research project, documented in a dissertation that is defended by the candidate in a public presentation.

   Candidates must write a dissertation conforming to university requirements that describes their work and results in detail. A public defense of the dissertation is required, and will be followed by a closed examination session. The committee for the closed examination shall consist of five faculty members, chosen by the Doctoral Program Committee, with at least two members being from outside the department. The outcome of the closed examination will be decided by majority vote of the committee. Because the closed examination
session fulfills the university Graduate Board Oral (GBO) examination requirement, all procedures pertaining to GBOs as established by the University Graduate Board must be followed.

The committee may impose certain conditions (e.g. changes to the dissertation) for the candidate to meet prior to final certification that he or she has passed the exam. For this reason, the thesis defense must be scheduled for a date at least two months prior to any personal or university deadline for degree completion. A complete draft of the dissertation must be submitted to all committee members no later than two weeks prior to the defense.

The dissertation in its final form must be read and approved in writing by two members of the committee (the adviser and one other member to be chosen by the committee as a whole).

Financial Aid

Merit and need-based grants, work-study opportunities, and federal student loans to undergraduate students are administered by the Office of Student Financial Services (http://www.jhu.edu/finaid). This office also provides access to federal student loans and work-study opportunities for graduate students.

MASTER’S DEGREE STUDENTS

Students who have graduated with a Johns Hopkins University undergraduate degree automatically earn a Dean’s Master’s Fellowship covering half of tuition for every semester of full-time enrollment in a WSE master’s degree program, provided they have either: (a) completed eight full-time semesters of study at Johns Hopkins, or (b) have not been enrolled at JHU for at least one year.

Students pursuing a combined bachelor’s and master’s degree who have not yet completed eight full-time semesters of study at Johns Hopkins, and have retained undergraduate status, are eligible to continue to apply for undergraduate financial aid through the Office of Student Financial Services.

- GoGrad Graduate Financial Aid (http://www.gograd.org/financial-aid)
- GoGrad Graduate Scholarships (http://www.gograd.org/financial-aid/scholarships)
- College Scholarships for Black Students (https://www.affordablecollegesonline.org/college-resource-center/black-students-college-scholarships)

Students who have completed all the coursework, other than research, required for an MSE degree in Materials Science and Engineering and are in good academic standing may be eligible for a Master’s Research Scholarship. Please see the following form for details.


PHD STUDENTS

Financial aid for full-time PhD candidates is provided directly from the Department of Materials Science and Engineering in the form of research assistantships and fellowships. All applicants to the PhD program are automatically considered for financial aid; there is no separate application.

Assistantships include:

- Full tuition support (100% first year tuition support provided by the Dean’s Office, in years 2-6, 80% tuition support from the Dean’s office, with the remaining 20% covered either by the student’s research advisor or by the department via fellowships)
- Stipend for living expenses ($30,200 for the 2019-2020 academic year)
- Individual health insurance

A list of estimated expenses for graduate study is available on the Homewood Graduate Student Affairs (https://homewoodgrad.jhu.edu/life-at-hopkins/costsandfunding) website.

Qualified PhD students are strongly encouraged to apply for external fellowships. These prestigious awards provide significant flexibility in the choice of advisor and research program. Examples include:

- National Science Foundation Graduate Research Fellowship (http://www/nsfgrfp.org)
- National Defense Science and Engineering Graduate Fellowship (http://ndseg.asee.org)
- Hertz Foundation Applied Science Fellowship (http://www.hertzfoundation.org)
- Computational Sciences Graduate Fellowship (http://www.krellinst.org/csgf)
- Stewardship Science Graduate Fellowship (http://www.krellinst.org/ssgf)

For current faculty and contact information go to http://materials.jhu.edu/index.php/people/

Faculty

Chair
Jonah Erlebacher
Professor: Nanostructured materials, self-organization and pattern formation, computational materials science, kinetics of shape change, ultra-high vacuum processing, nanoporous metals, fuel cells and energy.

Professors
Mingwei Chen
Professor: Research is primarily focused on the relationship between the structure and properties of advanced materials, particularly non-equilibrium and nanostructured materials.

Michael Falk
Professor: Theoretical and computational research investigating materials processes far from equilibrium: deformation, failure and fracture in non-crystalline materials such as metallic glasses; reactive materials, interactions of stress and diffusion in energy storage materials; mixing processes that accompany frictional sliding and wear.

Kalina Hristova
Professor: Biomolecular materials, structure and function of cellular membranes, membrane proteins, self-assembly of biological amphiphiles, protein-lipid interactions, protein synthesis, X-ray diffraction, fluorescence.

Todd C. Hufnagel
Professor: Mechanical properties and phase transformations in metals and ceramics; X-ray diffraction and X-ray phase-contrast imaging; 3D microstructural characterization; amorphous alloys

Howard E. Katz
Professor: Organic, hybrid, nanostructured, and interfacial materials in electronic and photonic devices; organic materials synthesis, thin film fabrication and patterning; novel architectures for devices, sensors, and circuits; host-guest chemistry, material responses to high electric fields; organic nonlinear optics; nanoparticles in biosystems; materials for physical science education.

En Ma
Professor: Metastable alloys including metallic glasses and nanostructured metals, phase-change alloys for memory applications, plasticity mechanisms, strength-ductility synergy, and high-entropy alloys

Hai-Quan Mao
Professor: Nanomaterials, electrospinning, nanofibers, biomimetic matrix, stem cell expansion and differentiation, nerve regeneration, micellar nanoparticle, therapeutic delivery, biodegradable polymers.

Peter C. Searson
Professor: biomaterials, tissue engineering

James B. Spicer
Professor: Ultrafast phenomena, laser interactions with materials, nanostructured composite materials, sensor physics, laser-based materials processing, elastic and anelastic materials properties, intelligent materials processing, near-field optical and microwave techniques.

Timothy P. Weihs
Professor: Exothermic reactions and phase transformations in films and powders, thermo-mechanical processing and mechanical properties of metals for structural and biodegradable applications, metallic 3D weaves for damping and biodegradable bone scaffolds

**Assistant Professors**

Luo Gu
Biomaterials, cell and tissue engineering, immunoengineering, nanomaterials, drug delivery, neuroengineering

Anthony Shoji Hall
Investigation of chemical reactions catalyzed by solid surfaces to address problems in renewable energy storage and utilization.

Tim Mueller
Computational materials discovery and design.

**Associate Research Professor**

Patricia M. McGuiggen
Adhesion, tribology, tribocharging, atomic force microscopy, interfacial phenomena, wetting, polymer and ceramic materials, heritage materials, paper conservation

**Associate Teaching Professor**

Orla Wilson
Associate Teaching Professor: nanomaterials, engineering education, assessment

**Research Faculty**

Kenneth Levi
Director of Materials Characterization & Processing Facility

**Joint, Part-Time, and Visiting Appointments**

Kit Bowen

E. Emmet Reid Professor (Chemistry): experimental chemical physics-photoelectron spectroscopy of negative ions, structure and dynamics of gas phase, weakly bound molecular clusters.

Collin Broholm
Gerhard H. Dieke Professor (Director, Institute for Quantum Matter) Physics & Astronomy: experimental condensed matter physics

Chia-Ling Chien
Jacob L. Hain Professor of Physics (Physics & Astronomy): Fabrication of experimental studies of structural, electronic, magnetic, and super-conducting properties of nanostructured solids; magneto-electronics, manipulation of small entities in low Reynolds number regime, biosensing.

Michael Edidin
Professor (Biology): membrane organization and dynamics, immunology studied with nanoparticles and advanced microscopy.

Jaafar El-Awady
Assistant Professor: Multiscale materials modeling, damage and fracture mechanisms of materials in mechanical design, material degradation in extreme environments, nano-materials and structures, impact dynamics and wave propagation.

Jennifer H. Elisseeff
Professor (Biomedical Engineering): tissue engineering, biomaterials, cartilage regeneration.

D. Howard Fairbrother
Professor (Chemistry): surface chemistry, electron induced deposition of nanostructured materials, environmental health and safety of nanomaterials.

Sharon Gerecht
Associate Professor (Chemical and Biomolecular Engineering): biomaterials, stem cells, biomimetic hydrogels, vascular differentiation, angiogenesis, regenerative medicine, hypoxia, microfluidics.

Somnath Ghosh
Professor (Civil Engineering): computational mechanics with focus on materials analysis, characterization and processing, including simulation and design.

David Gracias
Professor (Chemical & Biomolecular Engineering): micro and nanotechnology, surface science, metamaterials, complex systems, nanoelectrics, nanomedicine, regenerative medicine, drug delivery and microfluidics.

Warren Grayson
Assistant Professor (Biomedical Engineering): Tissue engineering, stem cells, bioreactors, biomaterials, orthopaedics

Jordan Green
Assistant Professor (Biomedical Engineering): cellular engineering, nanobiotechnology, biomaterials, controlled drug delivery and gene delivery.

Kevin J. Hemker
Professor (Mechanical Engineering): mechanical behavior of materials, transmission on electron microscopy, high temperature alloys, thermal barrier coatings, nanocrystalline materials and materials for MEMS.

Robert Ivkov
Visiting Assistant Professor, Radiation Oncology (JHU School of Medicine): development, characterization, and use of nanomaterials to target cancer and to enhance the effectiveness of other therapies such as radiation. A specific area of research includes the study and development of selective heating with magnetic nanoparticles.

Lynne Jones
Associate Professor (Orthopaedic Surgery, School of Medicine): biomaterials, osteonecrosis pathogenesis and treatment, total joint arthroplasty, bone graft materials.

Rangaramanujam Kannan
Professor: Ophthalmology, JHU School of Medicine

Feilim MacGabhann
Assistant Professor: computational modeling of growth factor-receptor networks, personalized medicine; individualized medicine; experimental studies of interindividual variation, therapeutic cardiovascular remodeling, novel methods for data visualization and automated image analysis, computational models of virus-host interactions.

Tyrel McQueen
Assistant Professor (Chemistry): Solid State and Inorganic Chemistry/Condensed Matter Physics

Thao (Vicky) Nguyen

K.T. Ramesh
Alonzo G. Decker Jr. Professor of Science and Engineering (Mechanical Engineering): Nanomaterials, planetary impact, dynamic failure mechanisms, shock, impact, and wave propagation, high-strain-rate behavior of materials, injury biomechanics, constitutive and failure modeling.

John D. Tovar
Professor (Chemistry): materials-oriented synthetic organic chemistry, electrochemistry, pi-conjugated and conducting polymers, supramolecular chemistry, organic electronics, biomimetic electronic materials.

Tza-Huei (Jeff) Wang
Professor (Mechanical Engineering): BioMEMS and microfluidics, single molecule manipulation and detection, nano/micro scale fabrication, conformational dynamics of biomolecules.

Denis Wirtz
Theophilus Halley Smoot Professor (Chemical and Biomolecular Engineering): cell adhesion and migration, cell mechanics, cytoskeleton physics, receptor-ligand interactions, cancer bioengineering, progeria, particle tracking methods.

Courses

EN.510.101. Introduction to Materials Chemistry. 3.0 Credits.
Basic principles of chemistry and how they apply to the behavior of materials in the solid state. The relationship between electronic structure, chemical bonding, and crystal structure is developed. Attention is given to characterization of atomic and molecular arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors, and polymers (including proteins). Examples are drawn from industrial practice (including the environmental impact of chemical processes), from energy generation and storage (such as batteries and fuel cells), and from emerging technologies (such as biomaterials). Students may receive credit for AS.030.103 or EN.510.101, but not both.
Prerequisites: Students may receive credit for AS.030.103 or EN.510.101, but not both.
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Natural Sciences

EN.510.105. Chocolate: An Introduction to Materials Science. 1.0 Credit.
This course will introduce students to some basic concepts in materials science including phase diagrams, crystallization, and various characterization techniques, all through the close examination of chocolate. Students will have the opportunity to try some of their own experiments to see these processes in action. This course is directed toward freshman or sophomore engineering and natural science students with no previous background in these topics.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Dailey
Area: Engineering, Natural Sciences

EN.510.106. Foundations of Materials Science & Engineering. 3.0 Credits.
Basic principles of materials science and engineering and how they apply to the behavior of materials in the solid state. The relationship between electronic structure, chemical bonding, and crystal structure is developed. Attention is given to characterization of atomic and molecular arrangements in crystalline and amorphous solids: metals, ceramics, semiconductors and polymers (including proteins). The processing and synthesis of these different categories of materials. Basics about the phase diagrams of alloys and mass transport in phase transformations. Introduction to materials behavior including their mechanical, chemical, electronic, magnetic, optical and biological properties.
Prerequisites: NA
Corequisites: NA
Instructor(s): E. Ma
Area: Engineering, Natural Sciences

For current course information and registration go to https://sis.jhu.edu/classes/
EN.510.107. Modern Alchemy. 3.0 Credits.
Can you really turn lead into gold? Converting common substances into useful materials that play important roles in today’s technologies is the goal of many modern scientists and engineers. In this course, we will survey selected topics related to modern materials, the processes that are used to make them as well as the inspiration that led to their development. Topics will include the saga of electronic paper, the sticky stuff of gecko feet and the stretchy truth of metal rubber.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Spicer
Area: Engineering, Natural Sciences
NA.

Through this course, students are introduced to the basic tenants of the field of materials science and engineering and important aspects of career development. Discussions will cover the range of career options in the field, the opportunities to engage with cutting edge research and technology at JHU, the skills that practitioners require and the ethical conundrums that engineering professionals navigate. Only available to Materials Science & Engineering freshmen and engineering undecided freshmen.
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
NA.

EN.510.135. MSE Design Team I. 3.0 Credits.
This course is the first half of a two-semester course sequence for freshmen majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE freshmen working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. Materials Science & Engineering Freshman Only. Recommended Course Background: EN.510.106, EN.510.109, or equivalent courses. *The team will meet 150 minutes per week at a time to be designated by the instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
NA.

EN.510.136. MSE Design Team I. 3.0 Credits.
This course is the second half of a two-semester course sequence for freshmen majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE freshmen working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. Materials Science & Engineering Freshman Only. Recommended Course Background: EN.510.106, EN.510.109, or equivalent courses. *The team will meet 150 minutes per week at a time to be designated by the instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.

EN.510.235. MSE Design Team I. 3.0 Credits.
This course is the first half of a two-semester course sequence for sophomores majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE freshmen working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. Materials Science & Engineering Sophomores Only. Recommended Course Background: EN.510.106, EN.510.109, or equivalent courses. *The team will meet 150 minutes per week at a time to be designated by the instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: NA
NA.

EN.510.236. MSE Design Team I. 3.0 Credits.
This course is the second half of a two-semester course sequence for sophomores majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE freshmen working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. Materials Science & Engineering Sophomores Only. Recommended Course Background: EN.510.106, EN.510.109, or equivalent courses. *The team will meet 150 minutes per week at a time to be designated by the instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.
EN.510.311. Structure Of Materials. 3.0 Credits.
First of the Introduction to Materials Science series, this course seeks to develop an understanding of the structure of materials starting at the atomic scale and building up to macroscopic structures. Topics include bonding, crystal structures, crystalline defects, symmetry and crystallography, microstructure, liquids and amorphous solids, diffraction, molecular solids and polymers, liquid crystals, amphiphilic materials, and colloids. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: (AS.110.106 AND AS.110.107) OR (AS.110.108 AND AS.110.109) OR (AS.110.107 AND AS.110.108) OR (AS.110.106 OR AS.110.109) AND (AS.030.103 OR(AS.030.101 AND AS.030.102)) AND ((AS.171.101 OR AS.171.103 OR AS.171.107) AND (AS.171.102 OR AS.171.104 OR AS.171.108))
Corequisites: NA
Instructor(s): A. Hall
Area: Engineering, Natural Sciences
NA.

EN.510.312. Thermodynamics/Materials. 3.0 Credits.
Second of the Introduction to Materials Science series, this course examines the principles of thermodynamics as they apply to materials. Topics include fundamental principles of thermodynamics, equilibrium in homogeneous and heterogeneous systems, thermodynamics of multicomponent systems, phase diagrams, thermodynamics of defects, and elementary statistical thermodynamics. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: Engineering, Natural Sciences
NA.

EN.510.313. Mechanical Properties of Materials. 3.0 Credits.
Third of the Introduction to Materials Science series, this course is devoted to a study of the mechanical properties of materials. Lecture topics include elasticity, anelasticity, plasticity, and fracture. The concept of dislocations and their interaction with other lattice defects is introduced. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: EN.510.311
Corequisites: NA
Instructor(s): T. Hufnagel
Area: Engineering, Natural Sciences
NA.

EN.510.314. Electronic Properties of Materials. 3.0 Credits.
Fourth of the Introduction to Materials Science series, this course is devoted to a study of the electronic, optical and magnetic properties of materials. Lecture topics include electrical and thermal conductivity, thermoelectricity, transport phenomena, dielectric effects, piezoelectricity, and magnetic phenomena. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: EN.510.311
Corequisites: NA
Instructor(s): H. Katz
Area: Engineering, Natural Sciences
NA.

EN.510.315. Physical Chemistry of Materials II. 3.0 Credits.
Fifth of the Introduction to Materials Science series, this course covers diffusion and phase transformations in materials. Topics include Fick’s laws of diffusion, atomic theory of diffusion, diffusion in multi-component systems, solidification, diffusional and diffusionless transformations, and interfacial phenomena. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: EN.510.311 AND EN.510.312
Corequisites: NA
Instructor(s): T. Mueller
Area: Engineering, Natural Sciences
NA.

EN.510.316. Biomaterials I. 3.0 Credits.
Sixth of the Introduction to Materials Science series, this course offers an overview of principles and properties of biomedical materials. Topics include properties of materials used in medicine, synthesis and properties of polymeric materials, polymeric biomaterials, natural and recombinant biomaterials, biodegradable materials, hydrogels, stimuli-sensitive materials, and characterizations of biomaterials. This course contains computational modules; some prior knowledge of computer programming is needed. Recommended Course Background: EN.510.202 (Computation and Programming for Materials Scientists and Engineers) or equivalent.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao
Area: Engineering, Natural Sciences
NA.

EN.510.335. MSE Design Team I. 3.0 Credits.
This course is the first half of a two-semester course sequence for freshmen, sophomores, and juniors majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE freshmen, sophomores, and juniors, working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. *The team will meet 150 minutes per week at a time to be designated by the instructor. Recommended Course Background: EN.510.101, EN.510.109, or equivalent courses.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson
Area: Engineering, Natural Sciences
NA.
EN.510.336. MSE Design Team I. 3.0 Credits.
This course is the second half of a two-semester course sequence for juniors majoring or double majoring in materials science and engineering (MSE). This course provides a broad exposure to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE juniors working with a team leader and seniors on the team, apply their general knowledge in MSE to develop the solution to open-ended problems. Materials Science & Engineering Freshman Only. Recommended Course Background: EN.510.106, EN.510.109, or equivalent courses. *The team will meet 150 minutes per week at a time to be designated by the instructor.
Prerequisites: EN.510.335
Corequisites: NA
Instructor(s): H. Mao; J. Spicer; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.

EN.510.400. Introduction to Ceramics. 3.0 Credits.
This course will examine the fundamental structure and property relationships in ceramic materials. Areas to be studied include the chemistry and structure of ceramics and glasses, microstructure and property relationships, ceramic phase relationships, and ceramic properties. Particular emphasis will be placed on the physical chemistry of particulate systems, characterization, and the surface of colloid chemistry of ceramics. Recommended Course Background: EN.510.311, EN.510.312; or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Engineering, Natural Sciences
NA.

EN.510.402. Soft Materials. 3.0 Credits.
The structure and properties of soft materials will be studied with the focus on understanding ways to control and measure the dynamics. Soft materials to be studied include colloids, emulsions, dispersions, drops, polymers and gels. We will use experimental tools to study these materials including optical microscopy, rheometers, and atomic force microscopy. Recommended Course Background: EN.510.311 or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: NA
Writing Intensive.

EN.510.403. Materials Characterization. 3.0 Credits.
This course will describe a variety of techniques used to characterize the structure and composition of engineering materials, including metals, ceramics, polymers, composites and semiconductors. The emphasis will be on microstructural characterization techniques, including optical and electron microscopy, X-ray diffraction, and thermal analysis and surface analytical techniques, including Auger electron spectroscopy, secondary ion mass spectroscopy, X-ray photoelectron spectroscopy, and atomic force microscopy. Working with the JHU museums, we will use the techniques learned in class to characterize historic artifacts.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Natural Sciences
NA.

EN.510.405. Materials Science of Energy Technologies. 3.0 Credits.
This course examines the science and engineering of contemporary and cutting-edge energy technologies. Materials Science and Mechanical Engineering fundamentals in this area will be complemented by case studies that include fuel cells, solar cells, lighting, thermoelectrics, wind turbines, engines, nuclear power, biofuels, and catalysis. Students will consider various alternative energy systems, and also to research and engineering of traditional energy technologies aimed at increased efficiency, conservation, and sustainability. Recommended Course Background: undergraduate course in thermodynamics.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: Engineering, Natural Sciences
NA.

EN.510.407. Biomaterials II: Host response and biomaterials applications. 3.0 Credits.
This course focuses on the interaction of biomaterials with the biological system and applications of biomaterials. Topics include host reactions to biomaterials and their evaluation, cell-biomaterials interaction, biomaterials for tissue engineering applications, biomaterials for controlled drug and gene delivery, biomaterials for cardiovascular applications, biomaterials for orthopedic applications, and biomaterials for artificial organs. Also listed as EN.510.607.
Prerequisites: EN.510.316 or permission of instructor.
Corequisites: NA
Instructor(s): L. Gu
Area: Engineering, Natural Sciences
NA.

EN.510.409. Melting, Smelting, Refining and Casting. 3.0 Credits.
This is a laboratory class on metal formation, an area that underlies almost all other technologies. We will examine extraction of metals from ore, refining of metals. The kinetics of melting and solidification will be explored in the context of casting and forming.
Prerequisites: EN.510.311 AND EN.510.312 AND EN.510.313 AND EN.510.315
Corequisites: NA
Instructor(s): T. Hufnagel
Area: Engineering, Natural Sciences
NA.

EN.510.412. Introduction to and Applications of Scanning Probe Microscopy. 3.0 Credits.
Scanning Probe Microscopy has emerged as one of the premier techniques to characterize surfaces. This course will give an overview of the family of SPM techniques including scanning tunneling microscopy (STM), atomic force microscopy (AFM), scanning near field optical microscopy (SNOM) and Kelvin probe microscopy. In each of these applications, the theory of operation, measurement and imaging techniques, and experimental limitations will be discussed. Also listed as 510.632.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Engineering, Natural Sciences
NA.
EN.510.414. Transmission electron microscopy: principle and practice. 3.0 Credits.
Introduction to basic principles of electron diffraction, phase contrast and Z-contrast and applications of these principles in microstructural characterization of materials by electron diffraction, high-resolution electron microscopy and scanning transmission electron microscopy. Also listed as EN.510.665.
Prerequisites: NA
Corequisites: NA
Area: Engineering, Natural Sciences
Instructor(s): M. Chen

EN.510.415. The Chemistry of Materials Synthesis. 3.0 Credits.
Many of the latest breakthroughs in materials science and engineering have been driven by new approaches to their synthesis, which has allowed the preparation of materials with fanciful structures and fascinating properties. This advanced course will explore synthetic approaches to multifunctional and nanostructured materials, ranging from opals to complex polymers to nanowires and quantum dots. Applications include electronics, energetic, and drug delivery. Participants will gain sufficient familiarity with synthesis options to be able to design research programs that rely on them. Emphasis will be placed on broad strategies that lead to material functionality, rather than detailed step-by-step sequences. Some topics will be selected “on the fly” from the most exciting current literature.
Prerequisites: NA
Corequisites: NA
Area: Engineering, Natural Sciences
Instructor(s): H. Katz

EN.510.416. Physical Behavior of Metamaterials. 3.0 Credits.
The field of metamaterials is a rapidly evolving area within the physical and engineering sciences that relates to diverse applications such as transformation optics for advanced imaging, acoustic noise reduction for architectural spaces and electromagnetic shielding for electronic devices. The goal of metamaterials design is to guide energy transport through specified regions of a material avoiding others that might contain delicate or otherwise susceptible structures that must be shielded. Energy transport can occur via electromagnetic waves, acoustic waves, electrical currents or thermal fluxes. Through rational design of the material micro/meso/macrostructure, any one of these can be effectively directed in the material. The challenge is to engineer materials that respond in a way that approximates the desired design. In this course, the methods for metamaterials design will be investigated along with those aspects of materials science and engineering that allow for the fabrication of these materials. Also listed as EN.510.616
Prerequisites: EN.510.31 AND EN.510.314 or their equivalents
Corequisites: NA
Instructor(s): J. Spicer
Area: NA

EN.510.420. Stealth Science & Engineering. 3.0 Credits.
The goal of stealth engineering is the creation of objects that are not easily detected using remote sensing techniques. To achieve this end, engineered systems of materials are arrayed to alter the signature of objects by reducing energy returned to remote observers. This course will provide an introduction to the general principles behind signature reduction by examining the mathematics and science behind basic electromagnetic and acoustic transport processes. Specific topics will include energy absorbing materials, anti-reflection coatings, wave guiding and scattering, metamaterials and adaptive screens. Co-listed with EN.510.640
Prerequisites: NA
Corequisites: NA
Area: Engineering, Natural Sciences
Instructor(s): J. Spicer

EN.510.421. Nanoparticles. 3.0 Credits.
Nanoparticles - one-dimensional materials with diameters of nearly atomic dimension - are one of the most important classes of nanostructured materials because their unusual properties that often differ significantly from bulk materials. This course will explore the synthesis, structure and properties of nanoparticles. Applications of nanoparticles in medicine, optics, sensing, and catalysis will be discussed, with an emphasis will be on metal nanoparticles and semiconductor quantum dots.
Prerequisites: NA
Corequisites: NA
Area: Engineering, Natural Sciences
Instructor(s): O. Wilson

EN.510.422. Micro and Nano Structured Materials & Devices. 3.0 Credits.
Almost every material’s property changes with scale. We will examine ways to make micro- and nano-structured materials and discuss their mechanical, electrical, and chemical properties. Topics include the physics and chemistry of physical vapor deposition, thin film patterning, and microstructural characterization. Particular attention will be paid to current technologies including computer chips and memory, thin film sensors, diffusion barriers, protective coatings, and microelectromechanical (MEMS) devices.
Prerequisites: NA
Corequisites: NA
Instructor(s): A. Hall; E. Ma
Area: Engineering, Natural Sciences

EN.510.426. Biomolecular Materials I - Soluble Proteins and Amphiphiles. 3.0 Credits.
This course will examine the fundamental structure, interactions, and function relationship for biological macromolecules. The course will emphasize experimental methods and experimental design, and the physics behind human disease. Topics will include micellization, protein folding and misfolding, and macromolecular interactions. Required Course Pre-Requisites: EN.580.221 & EN.510.312 - Co-listed with EN.510.621
Prerequisites: EN.580.221 AND EN.510.312
Corequisites: NA
Instructor(s): K. Hristova
Area: Engineering, Natural Sciences
NA.
EN.510.427. Chemistry of Nanomaterials. 3.0 Credits.
This course introduces the fundamental principles necessary to understand the behavior of materials at length scales larger than atoms or molecules with applications in chemistry and materials science. This course will explore topics such as nanoparticle synthesis and self-assembly, ordered porous materials, catalysis, nanostructured thin films, and solar energy conversion. Size dependent properties of nanomaterials will be discussed. Co-listed with EN.510.661.
Prerequisites: NA
Corequisites: NA
Instructor(s): A. Hall
Area: Engineering, Natural Sciences
NA.

EN.510.428. Material Science Laboratory I. 3.0 Credits.
This course focuses on characterizing the microstructure and mechanical properties of structural materials that are commonly used in modern technology. A group of A1 alloys, Ti alloys, carbon and alloy steels, and composite materials that are found, for example, in actual bicycles will be selected for examination. Their microstructures will be studied using optical metallography, scanning electron microscopy, X-ray diffraction, and transmission electron microscopy. The mechanical properties of these same materials will be characterized using tension, compression, impact, and hardness tests. The critical ability to vary microstructure and therefore properties through mechanical and heat treatments will also be demonstrated and investigated in the above materials. Restricted to Materials Science & Engineering juniors only
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Corequisites: Corequisites: EN.510.313
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.429. Materials Science Laboratory II. 3.0 Credits.
This laboratory concentrates on the experimental investigation of electronic properties of materials using basic measurement techniques. Topics include thermal conductivity of metal alloys, electrical conductivity of metals/metal alloys and semiconductors, electronic behavior at infrared wavelengths, magnetic behavior of materials, carrier mobility in semiconductors and the Hall effect in metals and semiconductors. Lab Assignment is by Professor. Recommended Course Background: EN.510.311 or Permission Required.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.430. Biomaterials Lab. 3.0 Credits.
This laboratory course concentrates on synthesis, processing and characterization of materials for biomedical applications, and characterization of cell-materials interaction. Topics include synthesis of biodegradable polymers and degradation, electrospinning of polymer nanofibers, preparation of polymeric microspheres and drug release, preparation of plasmid DNA, polymer-mediated gene delivery, recombinant protein synthesis and purification, self-assembly of collagen fibril, surface functionalization of biomaterials, cell culture techniques, polymer substrates for cell culture, and mechanical properties of biological materials. Recommended Course Background: EN.510.407
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Corequisites: NA
Instructor(s): K. Hristova
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.431. Senior Design Research. 3.0 Credits.
This course is the second half of a two-semester sequence required for seniors majoring or double majoring in materials science and engineering. It is intended to provide a broad exposure to many aspects of planning and conducting independent research. During this semester, students join ongoing graduate research projects for a typical 10-12 hours per week of hands-on research. Classroom activities include discussions, followed by writing of research pre-proposals (white papers), proposals, status reports and lecture critiques of the weekly departmental research seminar. Co-listed with EN.510.438 and EN.510.440
Prerequisites: (EN.510.311 AND EN.510.312 AND EN.510.313 AND EN.510.314 AND EN.510.315 AND EN.510.316) AND (EN.510.428 AND EN.510.429)
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering
Writing Intensive.

EN.510.432. Senior Design Research II. 3.0 Credits.
This course is the second half of a two-semester sequence required for seniors majoring or double majoring in materials science and engineering. It is intended to provide a broad exposure to many aspects of planning and conducting independent research. Recommended Course Background: EN.510.311-EN.510.312, EN.510.428-EN.510.429, and EN.510.433 Meets with EN.510.439, EN.510.441, EN.510.446, and EN.510.448
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.435. Mechanical Properties of Biomaterials. 3.0 Credits.
This course will focus on the mechanical properties of biomaterials and the dependence of these properties on the microstructure of the materials. Organic and inorganic systems will be considered through a combination of lectures and readings and the material systems will range from cells to bones to artificial implants. Same course as 510.635.
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Weihs
Area: Engineering, Natural Sciences
NA.
EN.510.438. Biomaterials Senior Design I. 3.0 Credits.
This course is the first half of a two-semester sequence required for seniors majoring in materials science and engineering with the Biomaterials Concentration. It is intended to provide a broad exposure to many aspects of planning and conducting independent research with a focus on biomaterials. During this semester, students join ongoing graduate research projects for a typical 10-12 hours per week of hands-on experiences in design and research. Classroom activities include discussions, followed by writing of research pre-proposals (white papers), proposals, status reports and lecture critiques of departmental research seminars. Co-listed with EN.510.440 and EN.510.433
Prerequisites: (EN.510.311 AND EN.510.312 AND EN.510.313 AND EN.510.314 AND EN.510.315 AND EN.510.316) AND (EN.510.428 AND EN.510.429)
Corequisites: NA
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.439. Biomaterials Senior Design II. 3.0 Credits.
This course is the second half of a two-semester sequence required for seniors majoring in materials science and engineering with the Biomaterials Concentration. It is intended to provide a broad exposure to many aspects of planning and conducting independent research with a focus on biomaterials. During this semester, verbal reporting of project activities and status is emphasized, culminating in student talks presented to a special session of students and faculty. Students also prepare a poster and a written final report summarizing their design and research results. Recommended Course Background: EN.510.311-EN.510.312, EN.510.428-EN.510.429, and EN.510.433 or 510.438 or 510.440 Meets with EN.510.434, EN.510.439, EN.510.446, and EN.510.448
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.440. Nanomaterials Senior Design I. 3.0 Credits.
This course is the first half of a two-semester sequence required for seniors majoring in materials science and engineering with the Nanotechnology Concentration. It is intended to provide a broad exposure to many aspects of planning and conducting independent research with a focus on nanotechnology and nanomaterials. During this semester, students join ongoing graduate research projects for a typical 10-12 hours per week of hands-on experiences in design and research. Classroom activities include discussions, followed by writing of research pre-proposals (white papers), proposals, status reports and lecture critiques of departmental research seminars. Co-listed with EN.510.433 and EN.510.438
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.441. Nanomaterials Senior Design II. 3.0 Credits.
This course is the second half of a two-semester sequence required for seniors majoring in materials science and engineering with the Nanotechnology Concentration. It is intended to provide a broad exposure to many aspects of planning and conducting independent research with a focus on nanotechnology and nanomaterials. During this semester, verbal reporting of project activities and status is emphasized, culminating in student talks presented to a special session of students and faculty. Students also prepare a poster and a written final report summarizing their design and research results. Recommended Course Background: EN.510.311-EN.510.312, EN.510.428-EN.510.429, and EN.510.433 or 510.438 or 510.440 Meets with EN.510.434, EN.510.439, EN.510.446, and EN.510.448
Prerequisites: NA
Corequisites: NA
Instructor(s): O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.442. Nanomaterials Lab. 3.0 Credits.
The objective of the laboratory course will be to give students hands on experience in nanotechnology based device fabrication through synthesis, patterning, and characterization of nanoscale materials. The students will use the knowledge gained from the specific synthesis, characterization and patterning labs to design and fabricate a working nanoscale/nanostructured device. The course will be augmented with comparisons to microscale materials and technologies. These comparisons will be key in understanding the unique phenomena that enable novel applications at the nanoscale. DMSE Seniors or permission of the instructor.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter 458083 in the Search box to locate the appropriate module.
Corequisites: NA
Instructor(s): O. Wilson; P. Mcguiggan
Area: Engineering, Natural Sciences
NA.

EN.510.443. Chemistry and Physics of Polymers. 3.0 Credits.
The course will describe and evaluate the synthetic routes, including condensation and addition polymerization, to macromolecules with varied constituents and properties. Factors that affect the efficiencies of the syntheses will be discussed. Properties of polymers that lead to technological applications will be covered, and the physical basis for these properties will be derived. Connections to mechanical, electronic, photonic, and biological applications will be made. Also listed as EN.510.643. Recommended Course Background: Organic Chemistry I and one semester of thermodynamics.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Katz
Area: Engineering, Natural Sciences
NA.
EN.510.444. MSE Bone Marrow Design Team. 3.0 Credits.
This course is the first half of a two-semester course sequence for senior students majoring or double majoring in MSE. This course provides current seniors with the opportunity to continue working on a design team project they were involved in as juniors while taking independent senior design (510.433 or equivalent). In this course, MSE seniors, working with a team leader and a group of freshmen, sophomores, and seniors, continue to apply their knowledge in their track area to generate the solution to open-ended problems encountered in MSE. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson
Area: NA
Writing Intensive.

EN.510.445. MSE Design Team II. 3.0 Credits.
This course is the first half of a two-semester course sequence for senior students majoring or double majoring in MSE. This course provides a broad experience to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE seniors, working with a team leader and a group of freshmen, sophomores, and seniors, apply their knowledge in their track area to generate the solution to open-ended problems encountered in MSE. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson
Area: Engineering, Natural Sciences
Writing Intensive.

EN.510.446. MSE Design Team II. 3.0 Credits.
This course is the second half of a two-semester course sequence for senior students majoring or double majoring in MSE. This course provides a broad experience to various aspects of planning and conducting independent research in a team setting (3 to 6 students on each team). In this course, MSE seniors, working with a team leader and a group of freshmen, sophomores, and seniors, apply their knowledge in their track area to generate the solution to open-ended problems encountered in MSE. Materials Science & Engineering Seniors Only. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429.
Prerequisites: EN.510.445
Corequisites: NA
Instructor(s): H. Mao; J. Spicer; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.

EN.510.447. MSE Design Team Leader. 4.0 Credits.
This course is the first half of a two-semester course sequence for students majoring or double majoring in MSE. This course provides a leadership experience to various aspects of planning and conducting independent research in a team setting. In this course, MSE seniors assemble and lead a student team consisting of 3 to 6 students, apply their knowledge in their track area, and develop leadership skills to generate the solution to open-ended problems encountered in MSE. Materials Science & Engineering Seniors Only. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429. Meets with EN.510.434, EN.510.439, EN.510.441, and EN.510.446
Prerequisites: EN.510.447
Corequisites: NA
Instructor(s): H. Mao; J. Spicer; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.

EN.510.448. MSE Design Team Leader. 4.0 Credits.
This course is the second half of a two-semester course sequence for students majoring or double majoring in MSE. This course provides a leadership experience to various aspects of planning and conducting independent research in a team setting. In this course, MSE seniors assemble and lead a student team consisting of 3 to 6 students, apply their knowledge in their track area, and develop leadership skills to generate the solution to open-ended problems encountered in MSE. Materials Science & Engineering Seniors Only. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429. Meets with EN.510.434, EN.510.439, EN.510.441, and EN.510.446
Prerequisites: EN.510.447
Corequisites: NA
Instructor(s): H. Mao; J. Spicer; O. Wilson; P. Searson
Area: Engineering, Natural Sciences
NA.

EN.510.449. MSE Bone Marrow Design Team II. 3.0 Credits.
This course is the second half of a two-semester course sequence for senior students majoring or double majoring in MSE. This course provides current seniors with the opportunity to continue working on a design team project they were involved in as juniors while taking independent senior design (510.433 or equivalent). In this course, MSE seniors, working with a team leader and a group of freshmen, sophomores, and seniors, continue to apply their knowledge in their track area to generate the solution to open-ended problems encountered in MSE. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; O. Wilson
Area: NA
Writing Intensive.
EN.510.450. Three Dimensional Microstructural Characterization of Materials. 3.0 Credits.
An undergraduate level introduction to experimental techniques and data analysis for characterizing the microstructure of materials in three dimensions. Topics to be covered include serial sectioning, principles of optical and scanning-electron microscopy and electron back-scatter diffraction (EBSD), high-energy x-ray diffraction microscopy, and techniques for 3D data reduction, representation, and analysis. Pre-Requisites: 510.311 & 510.313. Also listed as EN.510.701.
Prerequisites: EN.510.311 AND EN.510.313
Corequisites: NA
Instructor(s): T. Hufnagel
Area: Engineering, Natural Sciences
NA.

EN.510.457. Materials Science of Thin Films. 3.0 Credits.
The processing, structure, and properties of thin films are discussed emphasizing current areas of scientific and technological interest. Topics include elements of vacuum science and technology; chemical and physical vapor deposition processes; film growth and microstructure; chemical and microstructural characterization methods; epitaxy; mechanical properties such as internal stresses, adhesion, and strength; and technological applications such as superlattices, diffusion barriers, and protective coatings. Co-listed with EN.510.657
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Weihs
Area: Engineering, Natural Sciences
NA.

EN.510.459. Physics & Properties of Low-Dimensional Nanomaterials. 3.0 Credits.
This course is intended for advanced undergraduates and graduate students and will cover the fundamentals and properties of low dimensional nanomaterials. Subject matter will include a detailed and comprehensive discussion of the physics and physical properties of solids confined in either one, two or three directions. Features examined for these low dimensional materials will include electronic structure, electrical transport, vibrational and thermal transport in low dimensional systems such as graphene, carbon nanotubes, quantum wires, semiconductor and metal nanoparticles. Co-listed with EN.510.659.
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Poehler
Area: Engineering, Natural Sciences
NA.

EN.510.501. Undergraduate Research/Material Science. 3.0 Credits.
Student participation in ongoing research activities. Research is conducted under the supervision of a faculty member and often in conjunction with other members of the research group.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): Staff
Area: NA
NA.

EN.510.502. Research in Materials Science. 0.0 - 3.0 Credits.
Student participation in ongoing research activities. Research is conducted under the supervision of a faculty member and often in conjunction with other members of the research group.
Prerequisites: You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): Staff
Area: NA
NA.

EN.510.503. Independent Study/Materials Science. 3.0 Credits.
Individual programs of study are worked out between students and the professor supervising their independent study project. Topics selected are those not formally listed as regular courses and include a considerable design component.
Prerequisites: You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): Staff
Area: NA
NA.

EN.510.504. Independent Study. 0.0 - 3.0 Credits.
Individual programs of study are worked out between students and the professor supervising their independent study project. Topics selected are those not formally listed as regular courses and include a considerable design component.
Prerequisites: You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): A. Hall; P. Mcguiggan; P. Searson; T. Hufnagel
Area: NA
NA.

EN.510.511. Group Undergraduate Research/Material Science. 3.0 Credits.
Student participation in ongoing research activities. Research is conducted under the supervision of a faculty member and often in conjunction with other members of the research group. This section has a weekly research group meeting that students are expected to attend.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class. You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): Staff
Area: NA
NA.

EN.510.597. Research - Summer. 3.0 Credits.
NA
Prerequisites: You must request Independent Academic Work using the Independent Academic Work form found in Student Self-Service: Registration > Online Forms.
Corequisites: NA
Instructor(s): Staff
Area: NA
NA.
EN.510.601. Structure Of Materials. 3.0 Credits.
An introduction to the structure of inorganic and polymeric materials. Topics include the atomic scale structure of metals, alloys, ceramics, and semiconductors; structure of polymers; crystal defects; elementary crystallography; tensor properties of crystals; and an introduction to the uses of diffraction techniques (including X-ray diffraction and electron microscopy) in studying the structure of materials. Recommended Course Background: undergraduate chemistry, physics, and calculus or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): M. Chen
Area: NA
NA.

EN.510.602. Thermodynamics Of Materials. 3.0 Credits.
An introduction to the classical and statistical thermodynamics of materials. Topics include the zeroth law of thermodynamics; the first law (work, internal energy, heat, enthalpy, heat capacity); the second law (heat engines, Carnot cycle, Clausius inequality, entropy, absolute temperature); equilibrium of single component systems (free energy, thermodynamic potentials, virtual variations, chemical potential, phase changes); equilibrium of multicomponent systems and chemical thermodynamics; basics of statistical physics (single and multiple particle partition functions, configurational entropy, third law; statistical thermodynamics of solid solutions); and equilibrium composition-temperature phase diagrams. Recommended Course Background: undergraduate calculus, chemistry, and physics or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Searson
Area: NA
NA.

EN.510.603. Phase Transformations of Materials. 3.0 Credits.
This course presents a unified treatment of the thermodynamics and kinetics of phase transformations from phenomenological and atomistic viewpoints. Phase transformations in condensed metal and nonmetal systems are discussed. Recommended Course Background: EN.510.601 and EN.510.602
Prerequisites: NA
Corequisites: NA
Instructor(s): E. Ma
Area: NA
NA.

EN.510.604. Mechanical Properties of Materials. 3.0 Credits.
An introduction to the properties and mechanisms that control the mechanical performance of materials. Topics include mechanical testing, tensor description of stress and strain, isotropic and anisotropic elasticity, plastic behavior of crystals, dislocation theory, mechanisms of microscopic plasticity, creep, fracture, and deformation and fracture of polymers. Recommended Course Background: EN.510.601
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Weihs
Area: NA
NA.

EN.510.605. Electrical, Optical and Magnetic Properties of Materials. 3.0 Credits.
An overview of electrical, optical and magnetic properties arising from the fundamental electronic and atomic structure of materials. Continuum materials properties are developed through examination of microscopic processes. Emphasis will be placed on both fundamental principles and applications in contemporary materials technologies. Recommended Course Background: EN.510.601
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Spicer
Area: NA
NA.

EN.510.606. Polymer Chemistry & Biology. 3.0 Credits.
An introduction to the chemical and biological properties of organic and inorganic materials. Topics include an introduction to polymer science, polymer synthesis, chemical synthesis, and modification of inorganic materials, biomaterialization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins), and materials for biomedical applications. Recommended Course Background: undergraduate chemistry and biology or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): M. Herrera-Alonso
Area: NA
NA.

EN.510.607. Biomaterials II: Host response and biomaterials applications. 3.0 Credits.
This course focuses on the interaction of biomaterials with the biological system and applications of biomaterials. Topics include host reactions to biomaterials and their evaluation, cell-biomaterials interaction, biomaterials for tissue engineering applications, biomaterials for controlled drug and gene delivery, biomaterials for cardiovascular applications, biomaterials for orthopedic applications, and biomaterials for artificial organs. Recommended Course Background: Undergraduate chemistry and basic cell biology. Also listed as EN.510.407
Prerequisites: NA
Corequisites: NA
Instructor(s): L. Gu
Area: NA
NA.

EN.510.608. Fundamentals of Biomaterials. 3.0 Credits.
This course provides an introduction to biomaterials in medicine. Topics include: hard and soft biomaterials, materials science concepts specific to biomaterials, surface thermodynamics, surfactants and surface functionalization, proteins and protein-surface interactions, tissue engineering and regenerative medicine, wound healing and the inflammatory response, and drug delivery systems. Pre-requisites: 510.602 (Thermodynamics of Materials) or permission of instructor.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Mao; K. Hristova; L. Gu; P. Searson
Area: Engineering, Natural Sciences
NA.
EN.510.611. Solid State Physics. 3.0 Credits.
An introduction to solid state physics for advanced undergraduates and graduate students in physical science and engineering. Topics include crystal structure of solids; band theory; thermal, optical, and electronic properties; transport and magnetic properties of metals, semiconductors, and insulators. The concepts of solid state principles in modern electronic, optical, and structural materials are discussed. Crosslisted with Electrical and Computer Engineering.
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Poehler
Area: NA
NA.

EN.510.612. Solid State Physics. 3.0 Credits.
Basic solid state physics principles applied to modern electronic, optical, and structural materials. Topics discussed will include magnetism, superconductivity, polymers, nano-structured materials, electronic effects, and surface physics. For advanced undergraduates and graduate students in physical science and engineering. Recommended Course Background: EN.510.611
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Poehler
Area: NA
NA.

EN.510.614. Macromolecular Drug Carriers. 3.0 Credits.
In this course we will discuss recent literature findings regarding the design, synthesis, fabrication and characterization of macromolecular materials used as drug carriers. Topics include polymer synthesis, post-polymerization modification, structure-property relationships of nano-/micro-particles and hydrogels. Recommended Course Background: General Chemistry. Also listed as 510.401.
Prerequisites: NA
Corequisites: NA
Instructor(s): M. Herrera-Alonso
Area: Engineering, Natural Sciences
NA.

EN.510.615. Physical Properties of Materials. 3.0 Credits.
A detailed survey of the relationship between materials properties and underlying microstructure. Structure/property/processing relationships will be examined across a wide spectrum of materials including metals, ceramics, polymers and biomaterials, and properties including electrical, magnetic, optical, thermal, mechanical, chemical and biocompatibility.
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Engineering, Natural Sciences
NA.

EN.510.616. Physical Behavior of Metamaterials. 3.0 Credits.
The field of metamaterials is a rapidly evolving area within the physical and engineering sciences that relates to diverse applications such as transformation optics for advanced imaging, acoustic noise reduction for architectural spaces and electromagnetic shielding for electronic devices. The goal of metamaterials design is to guide energy transport through specified regions of a material avoiding others that might contain delicate or otherwise susceptible structures that must be shielded. Energy transport can occur via electromagnetic waves, acoustic waves, electrical currents or thermal fluxes. Through rational design of the material micro/meso/macrostructure, any one of these can be effectively directed in the material. The challenge is to engineer materials that respond in a way that approximates the desired design. In this course, the methods for metamaterials design will be investigated along with those aspects of materials science and engineering that allow for the fabrication of these materials. Also listed as EN.510.416
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Spicer
Area: NA
NA.

EN.510.621. Biomolecular Materials I - Soluble Proteins and Amphiphiles. 3.0 Credits.
Prerequisites: NA
Corequisites: NA
Instructor(s): K. Hristova
Area: Engineering, Natural Sciences
NA.

EN.510.632. Introduction to and Applications of Scanning Probe Microscopy. 3.0 Credits.
Scanning Probe Microscopy has emerged as one of the premier techniques to characterize surfaces. This course will give an overview of the family of SPM techniques including scanning tunneling microscopy (STM), atomic force microscopy (AFM), scanning near field optical microscopy (SNOM) and Kelvin probe microscopy. In each of these applications, the theory of operation, measurement and imaging techniques, and experimental limitations will be discussed. Also listed as EN.510.412
Prerequisites: NA
Corequisites: NA
Instructor(s): P. Mcguiggan
Area: Engineering, Natural Sciences
NA.
EN.510.633. Computational Materials Design. 3.0 Credits.
This course will cover the use of computational methods to discover and design materials for new technologies. Topics addressed will include structure prediction, materials informatics, and the calculation of material properties from first principles using methods such as density functional theory. Participants will gain hands-on experience with modern computational techniques.
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Mueller
Area: Engineering, Natural Sciences
NA.

EN.510.640. Stealth Engineering. 3.0 Credits.
The goal of stealth engineering is the creation of objects that are not easily detected using remote sensing techniques. To achieve this end, engineered systems of materials are arrayed to alter the signature of objects by reducing energy returned to remote observers. This course will provide an introduction to the general principles behind signature reduction by examining the mathematics and science behind basic electromagnetic and acoustic transport processes. Specific topics will include energy absorbing materials, anti-reflection coatings, wave guiding and scattering, metamaterials and adaptive screens. Co-listed with EN.510.420.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Spicer
Area: Engineering, Natural Sciences
NA.

EN.510.643. Chemistry and Physics of Polymers. 3.0 Credits.
The course will describe and evaluate the synthetic routes, including condensation and addition polymerization, to macromolecules with varied constituents and properties. Factors that affect the efficiencies of the syntheses will be discussed. Properties of polymers that lead to technological applications will be covered, and the physical basis for these properties will be derived. Connections to mechanical, electronic, photonic, and biological applications will be made. Also listed as EN.510.443. Recommended Course Background: Organic Chemistry I and one semester of thermodynamics.
Prerequisites: NA
Corequisites: NA
Instructor(s): H. Katz
Area: Engineering, Natural Sciences
NA.

EN.510.657. Materials Science of Thin Films. 3.0 Credits.
The processing, structure, and properties of thin films are discussed emphasizing current areas of scientific and technological interest. Topics include elements of vacuum science and technology; chemical and physical vapor deposition processes; film growth and microstructure; chemical and microstructural characterization methods; epitaxy; mechanical properties such as internal stresses, adhesion, and strength; and technological applications such as superlattices, diffusion barriers, and protective coatings. Co-listed with EN.510.457
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Weihns
Area: NA
NA.

EN.510.659. Physics & Properties of Low-Dimensional Nanomaterials. 3.0 Credits.
This course is intended for advanced undergraduates and graduate students and will cover the fundamentals and properties of low dimensional nanomaterials. Subject matter will include a detailed and comprehensive discussion of the physics and physical properties of solids confined in either one, two or three directions. Features examined for these low dimensional materials will include electronic structure, electrical transport, vibrational and thermal transport in low dimensional systems such as graphene, carbon nanotubes, quantum wires, semiconductor and metal nanoparticles. Co-listed with EN.510.459.
Prerequisites: NA
Corequisites: NA
Instructor(s): T. Poehler
Area: Engineering, Natural Sciences
NA.

EN.510.661. Chemistry of Nanomaterials. 3.0 Credits.
This course introduces the fundamental principles necessary to understand the behavior of materials at length scales larger than atoms or molecules with applications in chemistry and materials science. This course will explore topics such as nanoparticle synthesis and self assembly, ordered porous materials, catalysis, nanostructured thin films, and solar energy conversion. Size dependent properties of nanomaterials will be discussed. Co-listed with EN.510.427
Prerequisites: NA
Corequisites: NA
Instructor(s): A. Hall
Area: Engineering
NA.

EN.510.665. Transmission electron microscopy: principle and practice. 3.0 Credits.
Introduction to basic principles of electron diffraction, phase contrast and Z-contrast and applications of these principles in microstructural characterization of materials by electron diffraction, high-resolution electron microscopy and scanning transmission electron microscopy. Also listed as EN.510.414.
Prerequisites: NA
Corequisites: NA
Instructor(s): M. Chen
Area: Engineering, Natural Sciences
NA.

EN.510.701. Three-Dimensional Microstructural Characterization of Materials. 3.0 Credits.
A graduate-level introduction to experimental techniques and data analysis for characterizing the microstructure of materials in three dimensions. Topics to be covered include serial sectioning, principles of optical and scanning-electron microscopy and electron back-scatter diffraction (EBSD), high-energy x-ray diffraction microscopy, and techniques for 3D data reduction, representation, and analysis.
Prerequisites: EN.510.601 or Permission of instructor.
Corequisites: NA
Instructor(s): T. Hufnagel
Area: Engineering, Natural Sciences
NA.
EN.510.801. Materials Research Seminar. 1.0 Credit.
The Graduate Research Seminar in the Department of Materials Science and Engineering provides a forum for students to present their latest research results in a formal seminar setting. The course encourages discussion between students in varying disciplines in order to establish new collaborations and develop the shared vocabulary required for interdisciplinary materials science research. Permission Required.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

EN.510.802. Materials Research Seminar. 1.0 Credit.
NA
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

EN.510.803. Materials Science Seminar. 1.0 Credit.
The Materials Science Seminar exposes students to a wide array of internationally recognized speakers who discuss topics of cutting-edge Materials Science research. Speakers are selected both to overlap research interests within the department and to expose students to broader trends in contemporary Materials Science.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

EN.510.804. Materials Science Seminar. 1.0 Credit.
Meets with EN.510.434, EN.510.439, EN.510.441, EN.510.446, and EN.510.448.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

EN.510.807. Graduate Research In Materials Science. 3.0 - 20.0 Credits.
Individual programs of study are worked out between students and the professor supervising their independent study project. Topics selected are those not formally listed as regular courses and include a considerable design component.
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

EN.510.808. Graduate Research. 3.0 - 20.0 Credits.
NA
Prerequisites: NA
Corequisites: NA
Instructor(s): J. Erlebacher
Area: NA
NA.

Cross Listed Courses

Physics Astronomy
AS.171.321. Introduction to Space, Science, and Technology. 3.0 Credits.
Topics include space astronomy, remote observing of the earth, space physics, planetary exploration, human space flight, space environment, orbits, propulsion, spacecraft design, attitude control and communication. Crosslisted by Departments of Earth and Planetary Sciences, Materials Science and Engineering and Mechanical Engineering. Recommended Course Background: AS.171.101-AS.171.102 or similar; AS.110.108-AS.110.109.
Prerequisites: Students must have completed Lab Safety training prior to registering for this class.
Corequisites: NA

General Engineering
EN.500.112. Gateway Computing: JAVA. 3.0 Credits.
This course introduces fundamental programming concepts and techniques, and is intended for all who plan to develop computational artifacts or intelligently deploy computational tools in their studies and careers. Topics covered include the design and implementation of algorithms using variables, control structures, arrays, functions, files, testing, debugging, and structured program design. Elements of object-oriented programming, algorithmic efficiency and data visualization are also introduced. Students deploy programming to develop working solutions that address problems in engineering, science and other areas of contemporary interest that vary from section to section. Course homework involves significant programming. Attendance and participation in class sessions are expected.
Prerequisites: Students may not have earned credit in courses: EN.500.113 OR EN.500.114 OR EN.510.202 OR EN.520.123 OR EN.530.112 OR EN.580.200 OR EN.601.107.
Corequisites: NA
Instructor(s): I. Sekyonda; S. More
Area: Engineering
NA.

Electrical Computer Engineering
EN.520.627. Photovoltaics and Energy Devices. 3.0 Credits.
This course provides an introduction to the science of photovoltaics and related energy devices. Topics covered include basic concepts in semiconductor device operation and carrier statistics; recombination mechanisms; p-n junctions; silicon, thin film, and third generation photovoltaic technologies; light trapping; and detailed balance limits of efficiency. Additionally, thermophotovoltaics and electrical energy storage technologies are introduced. A background in semiconductor device physics (EN.520.485, or similar) is recommended.
Prerequisites: NA
Corequisites: NA
Instructor(s): S. Thon
Area: NA
NA.