

EN.510 (MATERIALS SCIENCE & ENGINEERING)

Courses

EN.510.106. Foundations of Materials Science & Engineering. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.121. Mitral Valve Design Team II. 3 Credits.

This is course is the second half of a two course sequences for students working on the Mitral Valve Design Team. The team will meet 150 minutes per week at a time designated by the instructor.

EN.510.135. MSE Design Team I. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.136. MSE Design Team II. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.221. Mitral Valve Design Team II. 3 Credits.

This is course is the second half of a two course sequences for students working on the Mitral Valve Design Team. The team will meet 150 minutes per week at a time designated by the instructor.

EN.510.235. MSE Design Team I. 3 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.

EN.510.236. Design Team II. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.311. Structure Of Materials. 3 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.

Prerequisite(s): ((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))); EN.500.113

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.312. Thermodynamics/Materials. 3 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.

Prerequisite(s): EN.510.311 AND EN.500.113

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.313. Mechanical Properties of Materials. 3 Credits.

An introduction to the properties and behavior of materials subjected to mechanical forces and deformation. Topics include the influence of composition and microstructure on the stiffness, strength, and toughness of materials. Particular emphasis is placed on fundamental mechanisms of deformation and fracture in the basic classes of materials (metals, ceramics, and polymers) as well as more complex materials (composites and biomaterials).

Prerequisite(s): EN.500.113 AND EN.510.312; EN.510.311 can be taken prior to enrolling in or at the same time as EN.510.313.

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.314. Electronic Properties of Materials. 3 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 conductivity and mobility, thermoelectricity, dielectric effects, piezoelectricity, photonic transmission and energetics, and magnetic phenomena. Mechanical force-based, quantum, and chemical explanations are presented and commonalities among them developed. Contemporary topics relevant to technology, sustainability, and medicine are explored.

Prerequisite(s): EN.510.311 AND EN.510.312

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.315. Physical Chemistry of Materials II. 3 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.

Prerequisite(s): EN.510.311 AND EN.510.312

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.316. Foundations of Biomaterials. 3 Credits.

As one of the six courses in the Introduction to Materials Science series, this course offers an overview of principles and properties of polymeric and soft materials for biomedical applications. Topics include synthesis and structure-property relationship of polymeric materials, natural and biomimetic materials, biodegradable materials, hydrogels and stimuli-sensitive materials, surface property and characterizations of biomaterials. Recommended Course Background: Introductory Organic Chemistry I (AS.030.205 or the equivalent).

Prerequisite(s): ((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 AND 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)) AND AS.030.205

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.321. Mitral Valve Design Team II. 3 Credits.

This course is the second half of a two course sequences for students working on the Mitral Valve Design Team. The team will meet 150 minutes per week at a time designated by the instructor

EN.510.335. MSE Design Team I. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.336. MSE Design Team II. 3 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.

Prerequisite(s): EN.510.335

Distribution Area: Engineering, Natural Sciences

EN.510.400. Introduction to Ceramics. 3 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.

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.402. Dynamics of Soft Materials. 3 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.

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.407. Biomaterials Principles and Applications. 3 Credits.

This course focuses on the interaction of biomaterials with the biological system and applications of biomaterials. Topics include biomaterials fabrication and characterization, host reactions to biomaterials, cell-biomaterials interaction, biomaterials for tissue engineering applications, biomaterials for controlled drug and gene delivery, and biomaterials for artificial organs.

Prerequisite(s): EN.510.316 OR (AS.030.205 AND EN.580.221) or Permission of Instructor

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.414. Transmission electron microscopy: principle and practice. 3 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.

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.419. Physical Metallurgy. 3 Credits.

Fundamentals of metals and modern alloy systems, emphasizing the development and stability of microstructure and the physical basis linking microstructure to mechanical properties. Topics include thermodynamics of alloy systems, solidification, phase transformations, mechanisms of deformation and fracture, and alloy design. Examples will be drawn from a variety of systems including ferrous alloys (steels), lightweight alloys (aluminum and magnesium), alloys for high temperature applications (superalloys), and recent developments including metallic glasses and high-entropy alloys.

Prerequisite(s): EN.510.311 AND EN.510.313 AND EN.510.315

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.420. Stealth Science & Engineering. 3 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

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.422. Micro and Nano Structured Materials & Devices. 3 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.

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.425. Advanced Batteries. 3 Credits.

This class provides an overview of the basic principles of electrochemical energy storage and the essential roles of advanced materials in batteries. Materials selection and design for the anodes and cathodes of lithium and sodium batteries are introduced on the basis of crystallography and materials chemistry. State-of-the-art operando characterization techniques of battery materials are also discussed in the course. This course is also listed as EN.510.625.

Prerequisite(s): Students who have taken, or are currently enrolled in, EN.510.625 are not eligible to take EN.510.425; EN.510.311 AND EN.510.312

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.426. Misfolding diseases and the thermodynamics of protein folding. 3 Credits.

This class is an overview of protein structure, folding, and interactions, with emphasis of protein misfolding and human disease. Topics include the hydrophobic effect, self assembly, thermodynamics of protein folding, kinetics of protein folding, and protein association. Special emphasis is placed on experimental techniques, including peptide synthesis, peptide separation and purification techniques, UV-vis, CD, fluorescence, calorimetry, mass-spec, etc. Co-listed with EN.510.621

Prerequisite(s): EN.580.221 AND EN.510.312

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.428. Materials Science Laboratory I. 3 Credits.

This course focuses on characterizing the microstructure and mechanical properties of structural materials that are commonly used in modern technology. A group of Al 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

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter Laboratory Safety Introductory Course in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); EN.510.311; EN.510.313 may be taken prior to enrolling in, or at the same time as, EN.510.428

Corequisite(s): EN.510.315 AND EN.510.313 must be taken at the same time as EN.510.428.

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

EN.510.429. Materials Science Laboratory II. 3 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.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); EN.510.311; EN.510.313 OR EN.510.314 can be taken prior to enrolling, or at the same time as, EN.510.429.

Corequisite(s): EN.510.314 must be taken at the same time as EN.510.429.

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

EN.510.430. Biomaterials Lab. 3 Credits.

This laboratory course focuses on the synthesis, characterization, and application of biomaterials in cellular and biomedical research. The class covers a broad range of scenarios where biomaterials play vital roles, including cell culture, gene delivery, tissue modeling, and cell sensing. Students will also learn the basic lab techniques in biomedical research, including cell and tissue cultures, heterologous gene expression, and cell imaging. Recommended Course Background: EN.510.407

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>)
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

EN.510.433. Senior Design Research. 3 Credits.

This course is the first 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

Prerequisite(s): (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)

Distribution Area: Engineering

AS Foundational Abilities: Science and Data (FA2)

Writing Intensive

EN.510.434. Senior Design/Research II. 3 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

Prerequisite(s): EN.510.433

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

Writing Intensive

EN.510.435. Mechanical Properties of Human Tissue: From Bones to Cells. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.436. Biomaterials for Cell Engineering. 3 Credits.

This course focuses on the development of biomaterials both as new tools to study fundamental biology and as means to direct cell behavior and function for biomedical applications. Topics include the material properties of cells and tissue, biomaterials for recapitulating cell microenvironment, biomaterials for studying and directing cell mechanotransduction, biomaterials for gene editing, biomaterials for immunotherapy, and biomaterials for neuroengineering. This course will have in-depth discussions on recent findings and publications in these areas. This course is also listed as EN.510.636.

Prerequisite(s): (EN.510.316 OR EN.510.407 OR EN.510.610)

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.438. Biomaterials Senior Design I. 3 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

Prerequisite(s): 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

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

Writing Intensive

EN.510.439. Biomaterials Senior Design II. 3 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.510.441, EN.510.446, and EN.510.448

Prerequisite(s): 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

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

Writing Intensive

EN.510.440. Nanomaterials Senior Design I. 3 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

Prerequisite(s): (EN.510.311 AND EN.510.312 AND EN.510.313 AND EN.510.314 AND EN.510.315 EN.510.316) AND (EN.510.428 AND EN.510.429)

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

EN.510.441. Nanomaterials Senior Design II. 3 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

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)
Writing Intensive

EN.510.442. Nanomaterials Lab. 3 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.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter Laboratory Safety Introductory Course in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>)
Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.443. Chemistry and Physics of Polymers. 3 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.

Distribution Area: Engineering, Natural Sciences
AS Foundational Abilities: Science and Data (FA2)

EN.510.445. MSE Design Team I. 3 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.

Prerequisite(s): 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

Distribution Area: Engineering, Natural Sciences
Writing Intensive

EN.510.446. MSE Design Team II. 3 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. Meets with EN.510.434, EN.510.439, EN.510.441 and EN.510.448.

Prerequisite(s): EN.510.445; 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

Distribution Area: Engineering, Natural Sciences

EN.510.447. MSE Design Team Leader. 4 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. Recommended Course Background: EN.510.101, EN.510.311, EN.510.312, EN.510.428, EN.510.429.

Distribution Area: Engineering, Natural Sciences
Writing Intensive

EN.510.448. MSE Design Team II Leader. 4 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

Prerequisite(s): EN.510.447

Distribution Area: Engineering, Natural Sciences

EN.510.451. Recycling for Sustainability. 3 Credits.

"I'm so confused...which bin do I choose?" Recycling everyday materials and re-using objects made from them have been part of our country's materials-usage landscape for decades. However, as we engineer a sustainable future, recycling will become an ever-increasing component of our strategies for material selection and product design. This course provides an overview of recycling – from the basics of materials recovery, processing and re-use to its economic and environmental impacts. Students will learn about industrial practices associated with recycling and how these relate to our everyday consumer behaviors. Field experiences and laboratory demonstrations will expose students to the realities of recycling. The challenges associated with recycling will be examined to gain a greater understanding of issues related to the use of materials in a sustainable world.

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.452. Materials in Extreme Environments. 3 Credits.

This survey course provides a broad perspective of the challenges materials face in evolving technologies related to energy production, aerospace, medicine, and even data storage. The course will introduce topics by technology and review the current materials in use, the challenges they face, and the future outlook in terms of opportunities, improvements, and research. Information will be provided from literature, media, and guest speakers from key industries and technology sectors.

EN.510.453. Materials Characterization. 3 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.

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.454. Nanomaterials for Genetic Medicine. 3 Credits.

This course describes how nanomaterials have facilitated and will advance genetic medicine in clinical applications for disease treatment and prevention. Topics of this course include synthesis and structure-activity relationship of hard and soft nanoparticles, biomimetic nanomaterials, nanomaterials for nucleic acid delivery, nanomaterials for genome editor delivery, biological fate of nanomaterials, and nano-bio interface characterization. This course will have in-depth discussions on recent progress and publications in these areas.

EN.510.456. Computational modeling of soft/bio materials. 3 Credits.

This course provides an overview of computational modeling methods with practical applications for designing soft materials and biomaterials. Computational methods include Monte Carlo, molecular dynamics, Bayesian analysis, machine learning, and the basics of finite-element modeling. The course is part project-based and teaches both the fundamentals of computational methods and how to apply them to current cutting-edge research in soft and biomaterials.

Prerequisite(s): Students who have taken or are enrolled in EN.510.656 are not eligible to take EN.510.456.; EN.500.113 AND EN.510.312

EN.510.457. Materials Science of Thin Films. 3 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

Distribution Area: Engineering, Natural Sciences

AS Foundational Abilities: Science and Data (FA2)

EN.510.466. Materials Modeling. 3 Credits.

Moore's law has given rise to the silicon age, where computational modeling can provide high-fidelity predictions to address challenges spanning climate change and renewable energy to economic stability and global pandemics. The skills to solve scientific problems computationally have become invaluable in virtually all industries. This introductory course is project-based and puts into practice the fundamentals of software development, numerical analysis, and scientific programming. Topics covered include methods for solving differential equations, Monte Carlo and atomistic simulations, machine learning, and data visualization. The course is taught in Python, and support for non-UNIX architectures is limited.

Prerequisite(s): EN.500.113 AND EN.510.311 AND EN.510.312

EN.510.501. Undergraduate Research in Material Science. 3 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.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter ASEN in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

EN.510.502. Research in Materials Science. 1 - 3 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.

Prerequisite(s): You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

EN.510.504. Independent Study. 1 - 3 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.

Prerequisite(s): You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

EN.510.511. Group Undergraduate Research/Material Science. 3 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.

Prerequisite(s): Students must have completed Lab Safety training prior to registering for this class. To access the tutorial, login to myLearning and enter Laboratory Safety Introductory Course in the Search Box to access the proper course. Click here to access the Laboratory Safety Introductory Course (<https://johnshopkins.csod.com/ui/lms-learning-details/app/curriculum/66847e20-c695-4e54-a6be-8c94465b8a70/>); You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

EN.510.597. Research - Summer. 1 - 3 Credits.

Undergraduates who want to do Independent Academic Work with a department faculty member in the summer must use the Independent Academic Work form found in Student Self-Service: Registration Online Forms.

Prerequisite(s): You must request Customized Academic Learning using the Customized Academic Learning form found in Student Self-Service: Registration > Online Forms.

EN.510.601. Structure Of Materials. 3 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.

EN.510.602. Thermodynamics Of Materials. 3 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.

EN.510.603. Phase Transformations of Materials. 3 Credits.

A detailed study of kinetic processes in materials is used to understand processing and microstructural evolution of materials. Topics include chemical rate equations, diffusion (equilibrium and non-equilibrium), interface thermodynamics, nucleation, solidification and crystal growth, phase transformations, and coarsening.

EN.510.604. Mechanical Properties of Materials. 3 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

Prerequisite(s): Students who have taken EN.530.604 are not eligible to take EN.510.604.

EN.510.605. Electrical, Optical and Magnetic Properties of Materials. 3 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

EN.510.606. Structure and Properties of Materials. 3 Credits.

Topics include types of materials, bonding in solids, basic crystallography, crystal structures, tensor properties of materials, diffraction methods, crystal defects, and amorphous materials.

Prerequisite(s): Students who have taken EN.510.601 OR EN.510.615 are not eligible to take EN.510.606.

EN.510.610. Fundamentals of Biomaterials. 3 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. No Audits.

Distribution Area: Engineering, Natural Sciences

EN.510.612. Thermodynamics and Kinetics of Materials. 3 Credits.

Topics include laws of thermodynamics, equilibrium of single and multiphase systems, chemical thermodynamics, statistical thermodynamics of solid solutions, equilibrium phase diagrams, chemical kinetics, diffusion in solids, nucleation and growth processes, coarsening, and glass transition.

Prerequisite(s): Students may not have previously taken EN.510.602 OR EN.510.603

EN.510.615. Physical Properties of Materials. 3 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. Distribution Area: Engineering, Natural Sciences

EN.510.617. Advanced Topics in Biomaterials. 3 Credits.

This course reviews recent advances in biomaterials, focusing on the design principles and cutting-edge applications of biomaterials. Topics include molecular and formulation designs, manufacturing and processing techniques, biointerface engineering, drug/gene delivery platforms, and regenerative engineering approaches. Essential techniques and biomaterials engineering platforms will also be discussed.

Prerequisite(s): EN.510.407 OR EN.510.610 OR Permission of Instructor

EN.510.619. Physical Metallurgy. 3 Credits.

Fundamentals of metals and modern alloy systems, emphasizing the development and stability of microstructure and the physical basis linking microstructure to mechanical properties. Topics include thermodynamics of alloy systems, solidification, phase transformations, mechanisms of deformation and fracture, and alloy design. Examples will be drawn from a variety of systems including ferrous alloys (steels), lightweight alloys (aluminum and magnesium), alloys for high temperature applications (superalloys), and recent developments including metallic glasses and high-entropy alloys.

Prerequisite(s): EN.510.601 AND EN.510.602;EN.510.603 AND (EN.510.604 OR EN.530.604)

Distribution Area: Engineering, Natural Sciences

EN.510.621. Misfolding diseases and the thermodynamics of protein folding. 3 Credits.

This class is an overview of protein structure, folding, and interactions, with emphasis of protein misfolding and human disease. Topics include the hydrophobic effect, self assembly, thermodynamics of protein folding, kinetics of protein folding, and protein association. Special emphasis is placed on experimental techniques, including peptide synthesis, peptide separation and purification techniques, UV-vis, CD, fluorescence, calorimetry, mass-spec, etc. Co-listed with EN.510.426

Distribution Area: Engineering, Natural Sciences

EN.510.622. Micro and Nano Structured Materials & Devices. 3 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. (Also listed as 510.622/422)

EN.510.624. X-ray Scattering, Diffraction, and Imaging. 3 Credits.

An introduction to the uses of x-rays for structural characterization of materials, including (i) kinematic theory of x-ray scattering and diffraction by single crystals, polycrystals, liquids, and amorphous solids; (ii) principles of Fourier optics with applications to x-ray radiography and phase-contrast x-ray imaging; and (iii) x-ray computed tomography (CT). Prerequisite: 510.601 or equivalent.

EN.510.625. Advanced Batteries. 3 Credits.

This course is designed to provide a comprehensive understanding of the principles underlying the development and operation of solid-state batteries, including the current state of the energy storage landscape. The course will delve into thermodynamics, kinetics, materials selection involved in solid-state battery design, interfacial electrochemistry, experimental methods, and practical considerations.

Prerequisite(s): Students who have taken, or are currently enrolled in, EN.510.425 are not eligible to take EN.510.625.;EN.510.601 AND EN.510.602

EN.510.627. Principles of biomolecular self-assembly and biological membranes. 3 Credits.

This course will focus on the structural and organizational principles for cellular membranes, and on structure-function relationships. Topics include the assembly of lipids in bilayers, the folding, the assembly, and the function of various classes of membrane proteins, and the methods used to study membrane processes.

EN.510.630. Molecular Simulation of Materials. 3 Credits.

Learn the fundamentals necessary to design and implement computer simulations on the molecular level. This course focuses on two widely used techniques: molecular-dynamics and Monte Carlo simulation. Both are introduced in the context of a review of the basic theoretical background. This class will cover the specifics of handling molecular interactions using empirical potentials, applying proper boundary conditions and simulating various equilibrium ensembles and non-equilibrium systems. Lectures will address how to extract transport coefficients, atomic scale correlations and local stresses and strains from simulation data, and computational issues such as algorithmic complexity and efficiency. The final weeks of the course will focus on new and cutting-edge advances in these methods.

Distribution Area: Engineering, Natural Sciences

EN.510.635. Mechanical Properties of Human Tissue: From Bones to Cells. 3 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 510.435

Distribution Area: Engineering, Natural Sciences

EN.510.636. Biomaterials for Cell Engineering. 3 Credits.

This course focuses on the development of biomaterials both as new tools to study fundamental biology and as means to direct cell behavior and function for biomedical applications. Topics include the material properties of cells and tissue, biomaterials for recapitulating cell microenvironment, biomaterials for studying and directing cell mechanotransduction, biomaterials for gene editing, biomaterials for immunotherapy, and biomaterials for neuroengineering. This course will have in-depth discussions on recent findings and publications in these areas. This course is also listed as EN.510.436.

EN.510.640. Stealth Engineering. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.643. Chemistry and Physics of Polymers. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.652. Materials in Extreme Environments. 3 Credits.

This survey course provides a broad perspective of the challenges materials face in evolving technologies related to energy production, aerospace, medicine, and even data storage. The course will introduce topics by technology and review the current materials in use, the challenges they face, and the future outlook in terms of opportunities, improvements, and research. Information will be provided from literature, media, and guest speakers from key industries and technology sectors.

EN.510.653. Materials Characterization. 3 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.

EN.510.654. Nanomaterials for Genetic Medicine. 3 Credits.

This course describes how nanomaterials have facilitated and will advance genetic medicine in clinical applications for disease treatment and prevention. Topics of this course include synthesis and structure-activity relationship of hard and soft nanoparticles, biomimetic nanomaterials, nanomaterials for nucleic acid delivery, nanomaterials for genome editor delivery, biological fate of nanomaterials, and nano-bio interface characterization. This course will have in-depth discussions on recent progress and publications in these areas.

EN.510.656. Computational modeling of soft/bio materials. 3 Credits.

This course provides an overview of computational modeling methods with practical applications for designing soft materials and biomaterials. Computational methods include Monte Carlo, molecular dynamics, Bayesian analysis, machine learning, and the basics of finite-element modeling. The course is part project-based and teaches both the fundamentals of computational methods and how to apply them to current cutting-edge research in soft and biomaterials.

Prerequisite(s): Students who are enrolled in or have taken EN.510.456 are not eligible to take EN.510.656.

EN.510.657. Materials Science of Thin Films. 3 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

EN.510.658. Electroanalytical Chemistry & Energy Conversion. 3 Credits.

Electrochemical methods are used by researchers in many fields to study topics such as (photo)electrocatalysis, batteries, and chemical sensors. This course will cover the basic theory and applications of electrochemistry to provide students with foundational knowledge of electrified solid-solution interfaces. Fundamental topics including interfacial charge transfer, mass transport, electric double layer structure, electrode kinetics, and analytical methods will be covered. State-of-the-art topics in electrochemistry research will also be discussed.

Distribution Area: Engineering

EN.510.662. Transmission Electron Microscopy: Methods. 3 Credits.

Transmission Electron Microscopy Methods is a hands-on, lab-based course design to give graduate students practical working knowledge of TEM methods. The course includes weekly 3 hr labs where students, in groups of four, will be instructed in the basic techniques needed to perform their characterization requirements of their research. In each lab students will learn a technique with which they will apply to a material and produce a report. Reports will be a transcription of steps taken in lab, documentation of data including images, spectra, measurements, and interpretation of data. At the end of the course, each group will produce a characterization report of a material of their choice.

EN.510.665. Transmission electron microscopy: principle and practice. 3 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.

Distribution Area: Engineering, Natural Sciences

EN.510.666. Materials Modeling. 3 Credits.

Moore's law has given rise to the silicon age, where computational modeling can provide high-fidelity predictions to address challenges spanning climate change and renewable energy to economic stability and global pandemics. The skills to solve scientific problems computationally have become invaluable in virtually all industries. This introductory course is project-based and puts into practice the fundamentals of software development, numerical analysis, and scientific programming. Topics covered include methods for solving differential equations, Monte Carlo and atomistic simulations, machine learning, and data visualization. The course is taught in Python, and support for non-UNIX architectures is limited.

EN.510.801. Materials Research Seminar. 1 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.

EN.510.802. Materials Research Seminar. 1 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 to establish new collaborations and develop the shared vocabulary required for interdisciplinary materials science research. Permission Required.

EN.510.803. Materials Science Seminar. 1 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.

EN.510.804. Materials Science Seminar. 1 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. Meets with EN.510.434, EN.510.439, EN.510.441, EN.510.446, and EN.510.448.

EN.510.807. Graduate Research In Materials Science. 3 - 20 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.

EN.510.808. Graduate Research. 3 - 20 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.

EN.510.809. Graduate Summer Research Course. 9 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.