PennState
College of Engineering

ENGINEERING SCIENCE
AND MECHANICS

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Engineering Science

Undergraduate Program Guide
2022- 2023

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Forward

The purpose of this document is to assist Engineering Science undergraduates in the planning of their academic programs and to enable them to derive maximum benefit from their affiliation with the Department. This guide also contains information regarding academic matters of interest to students, and provides a means for students to keep a record of their curriculum plans and courses taken.

The Department of Engineering Science and Mechanics is the departmental title resulting from the merger of the long-established Department of Engineering Mechanics and the Engineering Science Program, the College of Engineering Honors curriculum. Through this lineage, the Department has had a continuous existence for over seventy-five years. It has offered masters and doctoral degrees since 1940.

The baccalaureate major in Engineering Science was established in 1952 to provide an enriched inter-disciplinary program for students with special aptitude for graduate study and the pursuit of careers in creative aspects of engineering, including research and development. The first class of Engineering Science students graduated in 1956, and in 1963, the Engineering Science major was certified by the University as an Honors program. Since its inception, the Engineering Science program has graduated more than 1,000 students.

In 1974, as a result of economic considerations, the baccalaureate programs in Engineering Mechanics and Engineering Science, both highly regarded nationally, were merged under a single department with a new departmental name. The existing program in Engineering Science became the baccalaureate major for the Department, and it continues to be very highly regarded.

Because of its depth, breadth, and flexibility, the Engineering Science major provides an excellent opportunity for students who are interested in interdisciplinary training. Yet because of its flexibility, it can also be used to give tailored, focused training in engineering mechanics, electrical science, solid state and materials sciences, computer science, and bioengineering, to mention just a few possibilities.

It is interesting to note the results of a recent survey of Engineering Science undergraduates. They were asked to list their principal motivation for enrolling in Engineering Science. Almost equal numbers listed either the program's flexibility in planning a learning schedule or the program's extensive and practical applied science and mathematics background as their primary consideration. In (close) third place was the appreciation that the curriculum provides excellent training for a career in research and development. Some students listed the fact that the major is the official Honors program for the College of Engineering while others cited the excellent preparation for graduate school that it provides as their principal motivation for enrolling in Engineering Science.

In February 2005, an integrated undergraduate/graduate (IUG) program of study in the Engineering Science and Mechanics department was approved. The Schreyer Honors College also has an IUG program. These combined or integrated undergraduate/graduate programs offers students a number of scholastic advantages, not the least of which is a savings of time and money while obtaining a graduate degree. Details of the program are provided in Appendix B.

In 2014, Engineering Science introduced a new curriculum. In addition to creating a suite of foundational electives that includes biology and organic chemistry courses, the number of credits required for graduation has been reduced from 137 to 131. Details are given in Section 1.7.

It is hoped that you will retain this guide, read it carefully, and refer to it for assistance when the occasion arises. Along with your adviser, the entire faculty is ready to offer assistance when needed; do not hesitate to approach us.

The baccalaureate program in Engineering Science is accredited by the Engineering Accreditation Commission of ABET, Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202-4012; telephone 410-347-7700; or www.abet.org.

Chapter 1: ESC Curriculum Description

1. 1 —Engineering Science

Engineering Science is the discipline devoted to creating and optimizing engineered solutions through enhanced understanding and integrated application of mathematical, scientific, statistical, and engineering principles. Engineering Science provides the knowledge and motivation necessary to merge multidisciplinary resources, and propose enduring solutions that meet the profession's most demanding challenges.

1. 2 —The Engineering Scientist

The Penn State Engineering Science graduate obtains a solid understanding of the analytical, interpretive and extrapolative aspects of engineering. This unique knowledge enables a graduate to bridge the gap between theoretical science and practical engineering. The engineering scientist forgoes specialization in a single discipline for a broader perspective of engineering and the ability to interact with a team of allied professionals. Thus, the Engineering Science graduate in industry often finds himself/ herself functioning in a consultative capacity among other engineers.

1. 3 —The Engineering Science Curriculum

Engineering Science is a multidisciplinary honors program that emphasizes enhanced understanding and integrated application of engineering, scientific, and mathematical principles. The program is unique because it provides a broad foundation in the sciences and associated mathematics that underlie engineering and provides students the opportunity to obtain a depth of knowledge in an area of their choosing through technical electives and an honors thesis. The curriculum is designed for students who seek to link the engineering disciplines with science. In addition to taking core courses in mathematics, physics, chemistry, and biology, students study thermodynamics, heat transfer, electromagnetics, solid and fluid mechanics, electrical devices, materials science, and failure analysis. During the senior year, all students select a focus area of study, complete a capstone project and write a thesis that integrates the scientific principles of research, design and analysis and applies them to engineering. Focus areas of study include, but are not limited to, electrical, mechanical, civil, bioengineering, and materials and are typically interdisciplinary. Hence, Engineering Science students achieve both depth and breadth in engineering and science, are able to function across disciplines, and graduate well prepared for advanced studies as well as professional employment.

1. 4 —Student Outcomes

At the time of graduation, Engineering Science graduates are expected to attain an ability to apply knowledge of mathematics, science, and engineering.

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- 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
- an ability to communicate effectively with a range of audiences
- 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

- 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
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

1. 5 —Program Educational Objectives

The expected accomplishments of Engineering Science graduates in the first several years following graduation are:

1. acquire and apply new knowledge through lifelong learning activities including, but not limited to, masters, doctorate, medical, and law degrees, continuing education, leadership development, management training, innovation/entrepreneurship, and global involvement/awareness;

2. engage in practice in a wide variety of fields including, but not limited to, electrical systems, electronics, mechanical systems, materials development, forensics, biomaterials, medicine, law, and business in industry, academia and government;

3. research, develop, design and/or utilize new products, processes, materials, devices, systems, and/or tools;

4. communicate findings and best practices, at conferences and meetings, and to the general public through presentations, technical publications (journals, reports, memoranda), patents, and other media;

5. apply ethically and professionally the principles and latest tools of engineering, science, and mathematics for the benefit of society;

6. participate in and promote the values of diversity and sustainability in society; and

7. encourage and foster future generations of engineers through mentoring, service, and outreach.

1. 6—Keywords and Phrases in Engineering Science

- create and optimize engineered solutions
- integrated application of mathematical, scientific, statistical, and engineered principles
- integrate scientific principles of research, design and analysis with the applied art of engineering
- knowledge components: analytical to solve problems, interpretive to understand physics and reach conclusions, extrapolative to make decisions broad perspective of engineering and ability to interact with a team of allied professionals able to bridge the gap between theoretical science and practical engineering merge multidisciplinary resources, propose enduring solutions, meet demanding challenges work as a consultant among other engineering disciplines independently perform a capstone project in a timely manner multidisciplinary focus area of study honors and quality capstone project breadth with depth independent research consultant good communicator

1. 7 —Course Plans

(University Park and Commonwealth Campuses)

The curriculum in Engineering Science has been designed so that a student in this major can attend a Commonwealth Campus for the complete freshman and sophomore year before transferring to the University Park Campus, without delaying graduation.

The flowchart on page 13 shows the typical semester-by-semester placement of courses at University Park Campus and the flowchart on page 14 shows a similar flowchart for students interested in combining Engineering Science with the life/biological sciences. At a Commonwealth Campus, the differences are (1) that EMCH 211 plus EMCH 213 (6 credits) will replace EMCH 210H (5 credits) and (2) it is recommended that students complete their Health and Physical Activity requirement during their freshman and sophomore years. Course descriptions appear in Sections 1.8 and 1.9.

It should be noted that the 12 credits of senior technical electives and the three senior project courses, ESC 409H, ESC 410H and 411H, constitute 18 credits in an engineering area of the student's choice. This degree of flexibility enables students to gain excellent preparation for a career orientation of their choosing. *At least two of the technical elective credits must be engineering design and at least three must be engineering science.* The table in section 1.11 lists the engineering design/engineering science category content of many upper level engineering courses. It is in the student's best interest to select technical electives that support her or his senior project. Students should work with their project adviser and their academic adviser to plan to take the most appropriate technical electives.

1. 8 —Course Descriptions (Department Courses)

Note: Number in parenthesis is the credit count for the course

EMCH 197: Special Topics (1–9)

EMCH 210: Statics and Strength of Materials (5). Equilibrium of particles, rigid bodies, frames, trusses, beams, columns; stress and strain analysis of rods, beams, pressure vessels. Prerequisite: or concurrent: MATH 141

EMCH 210H: Equilibrium Mechanics, Honors (5). Equilibrium of particles and rigid bodies, frames, trusses, beams, columns; stress and strain analysis of rods, beams, pressure vessels. Prerequisite: or concurrent: MATH 141 [alternate course: EMCH 210 or EMCH 211 and EMCH 213]

EMCH 211: Statics (3). Equilibrium of coplanar force systems; analysis of frames and trusses; noncoplanar force systems; friction; centroids and moments of inertia. Prerequisite: or concurrent: MATH 141

EMCH 212: Dynamics (3). Motion of a particle; relative motion; kinetics of translation, rotation, and plane motion; work-energy; impulse-momentum. Prerequisite: EMCH 211 or EMCH 210; MATH 141

EMCH 212H: Mechanics of Motion, Honors (3). Motion of a particle; relative motion; kinetics of translation, rotation, and plane motion; work-energy; impulse-momentum. Prerequisite: EMCH 211, EMCH 210H, or EMCH 210; MATH 141 [alternate course: EMCH 212]

EMCH 213: Strength of Materials (3). Axial stress and strain; torsion; stresses in beams; elastic curves and deflection of beams; combined stress; columns. Prerequisite: EMCH 211

EMCH 296: Independent Studies (1 -18 per semester). Creative projects, including research and design, that are supervised on an individual basis and that fall outside the scope of formal courses.

EMCH 297: Special Topics (19). Formal courses given infrequently to explore, in depth, a comparatively narrow subject that may be topical or of special interest.

EMCH 302H: Thermodynamics, Heat Conduction, and Principles of Modeling, Honors (4).
EMCH 302H is a required course for engineering science students. This course presents the fundamental principles of classical thermostatics, thermodynamics, and heat transfer with relevant engineering applications. The students are expected to develop skills necessary to apply these principles to common engineering problems involving properties of matter, energy, non-reacting mixtures, and energy transport. Prerequisites: CHEM 110, PHYS 211, MATH 230; or MATH 231

EMCH 315: Mechanical Response of Engineering Materials (2). Mechanical response measures and design theories for engineering materials; elastic and plastic response as affected by stress, strain, time, temperature. Prerequisite: EMCH 213, EMCH 210H, or EMCH 210

EMCH 316: Experimental Determination of Mechanical Response of Materials (1). Experimental techniques for mechanical property measurement and structural testing. Prerequisite: or concurrent: EMCH 315

EMCH 397: Special Topics (1–9). Formal courses given infrequently to explore, in depth, a comparatively narrow subject that may be topical or of special interest.

EMCH 400: Advanced Strength of Materials and Design (3). Combined stresses; energy methods; special problems in bending and torsion; plates; thin-walled structures; buckling and stability; design projects. Prerequisite: EMCH 213, EMCH 210H, or EMCH 210

EMCH 402: Applied and Experimental Stress Analysis (3). Experimental design of structural and machine components; photoelasticity, electrical resistance strain gauge techniques, Moire techniques, interferometry, holography. Prerequisite: EMCH 213, EMCH 210H, or EMCH 210

EMCH 403: Strength Design in Materials and Structures (4). Determination, interpretation, significance, and application of mechanical properties such as plastic flow, fatigue strength, creep resistance, and dynamic properties. Prerequisite: EMCH 315, EMCH 316 or EMCH 416H (for ESC Students)

EMCH 407: Computer Methods in Engineering Design (3). Computer methods in mechanical design: solid modeling, graphics, surface smoothing/interpolation and underlying numerics: simultaneous equations, quadrature, eigen problems, discrete models.
Prerequisite: CMPSC 201C, CMPSC 201F, or ESC 261M; EMCH 213, EMCH 210H, or EMCH 210

EMCH 409: Advanced Mechanics (3). Continuation of E MCH 012; Euler's equations for the rotation of a rigid body, gyroscopic motion, impulsive motion, Lagrangian mechanics. Prerequisite: EMCH 212 or EMCH 212H; MATH 230

EMCH 416: Failure and Failure Analysis of Solids (3). (Honors Course). Examination and analysis of the various modes of failure of solid materials. Prerequisite: EMCH 213, EMCH 210, or EMCH 210H

EMCH 440 (MATSE): Nondestructive Evaluation of Flaws (3). Methods and limitations of nondestructive evaluation of mechanical flaws; optical, acoustical, electromagnetic, x-ray, radiography, thermography, and dye techniques. Prerequisite: EMCH 213, EMCH 210H, OR EMCH 210

EMCH 446: Mecahnics of Viscoelastic Matherials (3). Nature of viscoelastic materials, constitutive relations, thermorheological materials, viscoelastic stress analysis, rubber elasticity, viscoelastic liquids, experimental techniques for material characterization. Prerequisite: EMCH 315, EMCH 316

EMCH 461 (ME): Applied Finite Element Analysis (3). Computer modeling and fundamental analysis of solid, fluid, and heat flow problems using existing computer codes. Prerequisite: EMCH 213, EMCH 210H, or EMCH 210; CMPSC 200, CMPSC 201 or CMPSC 202

EMCH 470 (ME): Analysis and Design in Vibration Engineering (3). Application of Lagrange's equations to mechanical system modeling, multiple- degree-of-freedom systems, experimental and computer methods; some emphasis on design applications. Prerequisite: EMCH 212, or EMCH 212H; ME 370 or ESC 407H

EMCH 471: Engineering Composite Materials (3). Properties, manufacture, forms of composites; micromechanics; orthotropic lamina properties; laminate analysis; theories; failure analysis; thermal, environmental effects.. Prerequisite: EMCH 213, EMCH 210H, or EMCH 210; EMCH 315, ESC 414M, or MATSE 201

EMCH 473 (AERSP): Composites Processing (3). An introduction to the principles of mechanics governing manufacturing, computer-aided design, and testing of composite materials and structures. Prerequisite: EMCH 471

EMCH 480: Mechanism Design and Analysis (3). Design and analysis of mechanical linkages including kinematic synthesis and dynamic analysis. Linkages for a variety of applications are considered. Prerequisite: E MCH212 . Prerequisite or Concurrent: CMPSC200

EMCH 496: Independent Studies (1–18). Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

EMCH 497: Special Topics (1–9). Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

ESC 97: Special Topics (1-9). Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

ESC 120: Design for Failure – First Year Seminar (1). This seminar, through the utilization of commonly used examples, discusses the engineering principles which are exploited by such designs.

ESC 121: Science/Engineering Fiction and the Engineering Sciences – First Year Seminar (1). Examines the technology predictions of authors in view of the engineering sciences on which the underlying devices of their stories are based.

ESC 122: Weird, Wild, and Wonderful Materials and Devices – First Year Seminar (1). First-year seminar that surveys the use of novel materials and material systems to create practical devices.

ESC 123: Catastrophic Failures – First Year Seminar (1). First-year seminar that explores design deficiencies through the study of case histories of a number of famous failures.

ESC 211: Material, Safety and Equipment Overview for Nanotechnology (3). Nanotechnology processing equipment and materials handling procedures with a focus on safety, environment, and health issues. Prerequisite: CHEM 101 , MATH 081 , PHYS 150 or PHYS 250

ESC 212: Basic Nanotechnology Processes (3). Step-by-step description of equipment and processes needed in top-down, bottom-up, and hybrid nanotechnology processing. Concurrent: ESC 211

ESC 213: Materials in Nanotechnology (3). The processing of materials in nanotechnology as well as the unique material properties available at the nano-scale. Concurrent: ESC 211, ESC 212

ESC 214: Patterning for Nanotechnology (3). Pattern transfer techniques from photolightography to nanoimprinting and nanomolding. Concurrent: ESC 211, ESC 212

ESC 215: Nanotechnology Applications (3). Applications of nanotechnology including those in medicine, biology, electronics, energy, and materials. Concurrent: ESC 211

ESC 216: Characterization, Testing of Nanotechnology Structures and Materials (3). Measurements and techniques essential for controlling device fabrication. Concurrent: ESC 211, ESC 212

ESC 261: Computational Methods in Engineering, Honors, Writing Across the Curriculum (3). Computational methods for solving engineering problems using C++ and MATLAB. Reports on root finding, systems of algebraid equations. Prerequisite: or concurrent: MATH 141

ESC 296: Independent Studies (1–18). Creative projects, including research and design, that are supervised on an individual basis and that fall outside the scope of formal courses.

ESC 312: Engineering Applications of Wave, Particle, and Ensemble Concepts (3). The engineering applications of the wave and ensemble pictures of the physical world. Prerequisite: PHYS 214

ESC 313: Principles, Fabrication Methods, and Applications of Nanotechnology (3). Principles, fabrication methods and applications of nanoscale. Prerequisite: CHEM 110 , CHEM 111 , PHYS 212 , PHYS 214

ESC 314: Engineering Applications of Materials (3). Basic concepts of material structure and their relation to mechanical, thermal, electrical, magnetic, and optical properties, with engineering applications.(E SC 314 is not intended for students in E SC major) Prerequisite: PHYS 212

ESC 386: Engineering Principles of Living Organisms (3). This course will explore how engineering principles apply to living organisms. Prerequisite: CHEM 110, MATH 251 and PHYS 214

ESC 400: Electromagnetic Fields, Honors (3). Irrotational and solenoidal fields, potentials, vector and scalar field and wave equations, harmonic and wave functions in various coordinates, radiation. Prerequisite: EE 210 , MATH 250

ESC 404: Analysis in Engineering Science, Honors (3). Unified application of coordinate transformations; Laplace's, heat, and wave equations to boundary value problems and problems of continua in engineering. Prerequisite: MATH 250 or MATH 251

ESC 406: Analysis in Engineering Science II, Honors (3). Application of complex variable theory, integral equations, and the calculus of variations to engineering problems. Prerequisite: E SC 404H

ESC 407: Computer Methods in Engineering Science, Honors (3). Numerical solution of differential equations including fundamentals: roots of single nonlinear and simultaneous (Matrix) equations, least squares fitting and staistical goodness, interpolation, finite differences, differentiation, integration, eigensolutions. Prerequisite: CMPSC201 or CMPSC202 , or ESC 261M; Concurrent: MATH 220

ESC 409: Senior Design Project Preparation, Honors (1): Preliminary identification and planning for the senior year research and design project. Prerequisite: E SC 433H , E SC 414M

ESC 410: Senior Research and Design Project, Honors (3). Design and synthesis in the context of a specific design project undertaken during the senior year. Prerequisite: E SC 409H

ESC 411: Senior Research and Design Project II, Honors (2). Design and synthesis in the context of a specific design project undertaken during the senior year.

ESC 412: Nanotechnology: Materials, Infrastructure, and Safety (3). Cleanroom based nano/micro fabrication and related environmental health and safety issues. Prerequisite: 7th semester standing

ESC 414: Elements of Material Engineering, Honors, Writing Across the Curriculum (3). Structure and imperfections in engineered materials; their influence on properties, behavior, and processing. Applications of metals, ceramics, polymers, and composites. Prerequisite: EMCH213 , EMCH210H or EMCH210. Prerequisite or concurrent: ESC 312 or PHYS 237

ESC 417 (MATSE): Electrical and Magnetic Properties (3). Electrical conductivity, dielectric properties, piezoelectric and ferroelectric phenomena; magnetic properties of ceramics. Prerequisite: MATSE400 , MATSE413; Concurrent: MATSE402

ESC 419: Electronic Properties and Applications of Materials (3). The course covers the electrical, optoelectronic, dielectric, and other electron-based properties of solids, semiconductors in particular, and their engineering/ device applications. Prerequisite: E SC 312

ESC 430: Advanced Biofabrication Processes (3). This course covers advanced biofabrication processes used in tissue engineering, regenerative medicine and drug testing, and provides fundamental statistical concepts and tools that are required to analyze biofabrication process data. Prerequisite: At least 7th semester classification so that students have a technical background before taking the course.

ESC 433: Engineering Science Research Laboratory Experience, Honors (1). Hands-on lab experience and exposure to campus-wide interdisciplinary experimental research. Experimental probability and statistics. Appplications across all Engineering Science disciplines. Prerequisite: MATH 251

ESC 445: Semiconductor Optoelectronic Devices (3). The course will present the basic engineering science and technology involved in modern semiconductor optoelectronic devices. Prerequisite: E SC 419 or E SC 314 or E E 368

ESC 450 (MATSE): Synthesis and Processing of Electronic and Photonic Materials (3). The materials science of applying thin film coatings, etching, and bulk crystal growth; includes materials transport, accumulation, epitaxy, and defects. Prerequisite: MATSE201 or ESC 414H , sixth semester standing

ESC 455 (MATSE): Electrochemical Methods in Corrosion Science and Engineering (3). The objective of the course is to give students hands-on experience in assessing environmental degradation of engineering materials. Prerequisite: MATSE259 or ESC 414M or EGEE 441

ESC 460M: Multidisciplinary Design Project, Honors, Writing Across the Curriculum (3): This course will provide students with the opportunity to learn the design process in the context of an industry- or government-sponsored or service-based design project that demands delivering a working solution. The design projects in this course will be structured for students from two or more different engineering majors, as defined by the project sponsors in collaboration with the instructor and departmental project coordinators. Prerequisites: Senior standing in the students major or junior standing in Engineering Science Honors Curriculum or Schreyer Honors College. CHEM 110, MATH 140, MATH 141, MATH 250; or MATH 251, PHYS 211; or PHYS 212

ESC 460W: Multidisciplinary Design Project, Writing Across the Curriculum (3): This course will provide students with the opportunity to learn the design process in the context of an industry- or government-sponsored or service-based design project that demands delivering a working solution. The design projects in this course will be structured for students from two or more different engineering majors, as defined by the project sponsors in collaboration with the instructor and departmental project coordinators. Prerequisite: CHEM 110, MATH 140, MATH 141, MATH 250; or MATH 251, PHYS 211; or PHYS 212

ESC 475 (MATSE): Particulate Materials Processing (3). Fundamentals of processing particulate materials including production, characterization, handling, compaction, and sintering of metal, carbide, intermetallic, and composite powders. Prerequisite: EMCH 315, ESC 414, OR MATSE 259

ESC 481: Elements of Nano/Micro-electromechanical Systems Processing and Design (3). Interdisciplinary fundamentals of nano/microelectromechanical systems (NEMS/ MEMS), including design, fabrication and machining of miniature systems. Draws from mechanics, science and materials. Prerequisite: EMCH213, or EMCH315, or ESC 312

ESC 482: Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics (3). Principles and applications of Micro-Optoelectromechanical and Nanophotonic devices and systems. Prerequisite: PHYS 212, PHYS 214

ESC 483 (MATSE): Simulation and Design of Nanostructures (3). Introduction to computer simulation techniques and their applications at the physical/life sciences interface. Prerequisite: PHYS 214 or ESC 312, MATH 230

ESC 484: Biologically Inspired Nanomaterials (3). Advances in biomolecular-based Science and technology at the physical/life sciences interface. Prerequisite: PHYS 214 , MATH 230

ESC 494: Senior Thesis (1–9). Students must have approval of a thesis adviser before scheduling this course.

ESC 494H: Senior Thesis, Honors (1–9). Students must have approval of a thesis adviser before scheduling this course.

ESC 496: Independent Studies (1-18). Creative projects, including research and design, which are supervised on an individual basis and which fall outside the scope of formal courses.

ESC 497: Speical Topics (1-9). Formal courses given infrequently to explore, in depth, a comparatively narrow subject which may be topical or of special interest.

1. 9 —Course Descriptions (Other Courses)

AERSP 308 Mechanics of Fluids (3). Kinetics and dynamics of fluids; perfect fluid theory using complex variables; introduction to viscous flow theory; fundamentals of compressible flow. Prerequisite: EMCH 212 or EMCH 212H; MATH 251

BIOL 141 (GN) Introductory Physiology (3). Explanation of the normal structure and function of the animal body, with special emphasis on human body systems. Students who have passed BIOL 472 may not schedule this course.

CAS 100A (GWS) Effective Speech (3). Principles of communication, implemented through presentation of speeches, with some attention to group discussion and message evaluation.

CAS 100B (GWS) Effective Speech (3). Principles of communication, implemented through group problem solving, with some attention to formal speaking and group discussion.

CHEM 110 (GN) Chemical Principles (3). Basic concepts and quantitative relations.

CHEM 111 (GN) Experimental Chemistry (1). An introduction to quantitative experimentation in chemistry.

CHEM 112 (GN): Chemical Principles (3). Continuation of CHEM 111 including an introduction to the chemistry of the elements.

CHEM 210 Organic Chemistry (3). Principles and theories; nomenclature; chemistry of the functional groups; applications of spectroscopy. Students may not receive credit for both CHEM 210 and 034. Prerequisite: CHEM 112

EDSGN 100 Introduction to Engineering Design (3): Introduction to engineering design through team-oriented design projects supported by communication skills: graphical, verbal, written.

EE 210H Circuits and Devices, Honors (4). Introduction to electrical circuit analysis, electronic devices, amplifiers, and time-domain transient analysis. Prerequisite: PHYS 202 or PHYS 212. Prerequisite or concurrent: MATH 250

ENGL 202C (GWS) Effective Writing: Technical Writing (3): Writing for students in scientific and technical disciplines. (A student may take only one course for credit from ENGL 202A, 202B, 202C and 202D) Prerequisite: ENGL 015 or ENGL 030; fourth- semester standing.

MATH 140 (GQ): Calculus with Analytic Geometry I (4). Functions, limits; analytic geometry; derivatives, differentials, applications; integrals, applications. Students may only take one course for credit from MATH 110, 140, 140A, and 140B. Prerequisite: MATH 022, MATH 026; or MATH 040 or MATH 041 or satisfactory performance on the mathematics proficiency examination

MATH 141 (GQ): Calculus with Analytic Geometry II (4). Derivatives, integrals, applications; sequences and series; analytic geometry; polar coordinates. Students may take only one course for credit from MATH 141 and 141B. Prerequisite: MATH 140, MATH 140A, or MATH 140B

MATH 220 (GQ): Matrices (2). Systems of linear equations; matrix algebra; eigenvalues and eigen-vectors; linear systems of differential equations. Prerequisite: MATH 110 or MATH 140

MATH 230 Calculus and Vector Analysis (4). Three-dimensional analytic geometry; vectors in space; partial differentiation; double and triple integrals; integral vector calculus. Students who have passed either Math 231 or 232 may not schedule Math 230 for credit. Prerequisite: MATH 141

MATH 251 Ordinary and Partial Differential Equations (4). First and second-order equations; special functions; Laplace transform solutions; higher order equations; Fourier series; partial differential equations. Prerequisite: MATH 141

PHYS 211 (GN) General Physics: Mechanics (4). Calculus-based study of the basic concepts of mechanics: motion, force, Newton's laws, energy, collisions, and rotation. Concurrent: MATH 140

PHYS 212 (GN) General Physics:Electricity and Magnetism (4). Calculus-based study of the basic concepts of electricity and magnetism. Prerequisite: MATH 140, PHYS 211. Concurrent: MATH 141

PHYS 214 (GN) General Physics: Wave Motion and Quantum Physics (2). Effective Date: SP2004: Calculus-based study of the basic concepts of wave motion, geometrical optics, interference phenomena, photons, wave mechanics, and the structure of matter. Prerequisite: MATH 140, PHYS211. Concurrent: MATH 141

1. 10 —Foundational Electives

The intention of the Foundational Elective (FE) courses is to provide some flexibility in the junior year courses while maintaining a high level of technical content (not meant for intro/overview courses), providing breadth of topics covered (not to become a junior year area of concentration), and support potential deeper study in the senior year.

A total of 5 FE courses are required for graduation (See Table 1). Some courses on these lists are suitable as *Technical Electives*, but each course can only be used to fulfill one degree requirements, *either* a Foundational Elective or a Technical Elective.

Students must complete courses selected from the following lists for a total of 15 to 17 credits. **No more than one 100-level course may be used.** Please note the distribution of courses**. At least 3 need to come from the Core list.** The remaining two courses can be from the Core list or the Alternative list.

E SC Foundational Electives

The intent of the Foundational Elective (FE) courses is to provide some flexibility in the junior year while maintaining a high level of technical content (i.e., not intro/overview courses), providing breadth of topics covered, and supporting potential deeper study in the senior year.

A total of five FE courses are required. Some courses on these lists are suitable as Technical Electives, but each course can be used to fill one degree requirement. No more than one 100-level course may be used.

Core (select 3–5 courses)

- CHEM 112 (Chemical Principles II)
- AERSP 308H (Mechanics of Fluids)
- E MCH 416H (Failure and Failure Analysis of Solids)
- E SC 400H (Electromagnetic Fields)
- E SC 419 (Electronic Properties and Applications of Materials)

The following are acceptable core subtitutions:

- AERSP 308H ➔ AERSP 311, BME 409, CH E 330H, C E 360, EME 303, or M E 320
- E SC 419 ➔ E SC 314
- E SC 400H ➔ E E 330 or PHYS 400

Alternative (select 0–2 courses)

- AERSP 301 (Aerospace Structures)
- AERSP 304 (Dynamics & Control of Aerospace Systems)
- AERSP 309 (Astronautics)
- AERSP 312 (Aerodynamics II)
- A E 311 (Fundamentals of Electrical and illumination Systems for Building)
- B E 300 (Biological Systems)
- B E 302 (Transport Processes for B E) B E 304
- (Engineering Properties of Food and Biological Materials)
- B E 306 (Machines for Agricultural & Biological Processing)
- B M B 251 (Molecular and Cell Biology I)
- BME 201 (Cell and Molecular Bioengineering)
- BME 301 (Analysis of Physiological Systems)
- BME 303 (Bio-continuum Mechanics)
- BIOL 110 (Biology: Basic Concepts and Biodiversity)
- BIOL 141 (Introductory Physiology)
- BIOL 230M (Molecules and Cells)
- BIOL 240M (Function and Development of Organisms)
- C E 340 (Structural Analysis)
- C E 335 (Engineering Mechanics of Soils)
- C E 370 (Introductions to Environmental Engineering)
- CH E 210H (Introduction to Material Balances)
- CH E 320H (Phase and Chemical Equilibria)
- CHEM 210 (Organic Chemistry)
- CMPEN 270 (Digital Design: Theory and Practice)
- CMPEN 331 (Computer Organization and Design)
- CMPSC 122 (Intermediate Programming)
- CMPSC 221 (Object Oriented Programming with Web-Based Applications)
- CMPSC 311 (Introduction to Systems Programming)
- CMPSC 312 (Computer Organization and Architecture)
- CMPSC 360 (Discrete Mathematics for Computer Science)
- E E 310 (Electronic Circuit Design 1)
- E E 320 (Introduction to Electro-Optical Engineering)
- E E 340 Introduction to Nanoelectronics)
- E E 350 (Continuous-Time Linear Systems)
- E SC 313 (Intro to Principles, Fabrication Methods, and Appl. of Nanotechnology)
- E SC 3xx (Physical Principles of Living Organisms)
- E SC 4xx (Multidisciplinary Design Project)
- EGEE 302 (Principals of Energy Engineering)
- EGEE 304 Heat and mass Transfer)
- ENGR 320 (Materials Properties Measurement I)
- I E 305 (Product Design, Specification & Measurement)
- I E 311 (Principles of Solidification Processing)
- I E 312 (Product Design and Manufacturing Processes)
- I E 322H (Probabilistic Models in I E)
- I E 323 (Statistical Methods in I E)
- I E 327 (Introduction to Work Design)
- I E 330 (Information Technology for I E)
- M E 360 (Mechanical Design)
- M E 367 (Machine Design)
- M E 370 (Vibration of Mechanical Systems)
- M E 380 (Machine Dynamics)
- MATH 311M (Concepts of Discrete Mathematics)
- MATH 315 (Foundations of Mathematics)
- MATSE 400 (Crystal Chemistry)
- MATSE 402 (Materials Process Kinetics)
- MATSE 443 (Introduction to the Materials Science of Polymers)
- METEO 300 (Fundamentals of Atmospheric Science)
- NUCE 301 (Fundamentals of Reactor Physics)
- NUCE 309 (Analytical Techniques for Nuclear Concept)

Electronic Petitions are accepted for courses not found on this list. The student must demonstrate in the petition a) that the proposed FE course is highly technical, not just introductory, b) combined with the other selected FE courses, the proposed FE course adds to the breadth in the junior year, and c) how the proposed FE course supports the student's intended senior year focus (perhaps as a prerequisite to intended Technical Elective courses).

Petitions must now be submitted online using the Course Substitution Request System. You can access the system at coursesub.psu.edu

1. 11 —Technical Electives

The purpose of the *technical elective* courses is to enable students to pursue broader studies in selected subjects related to their chosen field. These courses are selected by each student from the list shown in Table 1. Other courses may be permitted by petition.

Consistent with the objectives of the Engineering Science curriculum, *at least two credits of technical electives must be taken in engineering design and at least three in engineering science*. The following definitions have been adopted to distinguish between the two.

The *engineering sciences* have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other.

Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

Table 2 provides the list of Technical Electives and a breakdown for the Engineering Science Program. Co-op students may substitute three credits, one for each work experience (ENGR 295, 395, 495), as a technical elective provided the student satisfactorily completes all three work assignments for a letter grade. These three credits will be considered to be in the engineering design category.

E SC Technical Electives

A total of four Technical Elective (TE) courses are required.

Engineering Courses (select 2–4 courses)

Courses in **boldface type** can be used as *either* as a Technical Elective or as a Foundational Elective.

- AERSP 412 (Turbulent Flow)
- AERSP 424 (Advanced Computer Programming)
- AERSP 440 (Introduction to Software Engineering for Aerospace Engineers)
- AERSP 460 (Aerospace Control Systems)
- AERSP 473 (Composites Processing)
- AERSP 490 (Introduction to Plasmas)
- AERSP 492 (Space Astronomy and Introduction to Space Science)
- A E 421 (Architectural Structural Systems I)
- A E 424 (Environmental Control Systems I)
- A E 430 (Indeterminate Structures)
- A E 456 (Solar Energy Building System Design)
- A E 461 (Architectural Illumination Systems & Design)
- A E 464 (Advanced Architectural Illumination Systems & Design)
- A E 467 (Advanced Building Electrical System Design)
- A E 470 (Residential Building Design and Construction)
- BME 402 (Biomedical Instrumentation and Measurements)
- BME 406 (Medical Imaging)
- BME409 (Biofluid Mechanics)
- BME 410 (Biomedical Applications of Microfluidics)
- BME 413 (Mass Transport in Biological Systems)
- BME 419 (Artificial Organs and Prosthetic Devices)
- BME 423 (Reaction Kinetics of Biological Systems)
- BME 443 (Biomedical Materials)
- BME 444 (Surfaces and the Biological Response to Materials)
- BME 445 (Tissue Engineering: Concepts, Calculations and Applications)
- B E 461 (Design of Fluid Power Systems)
- B E 465 (Food and Biological Process Engineering)
- B E 467 (Design of Stormwater and Erosion Control Facilities)
- B E 468 (Microbiological Engineering)
- B E 477 (Land-Based Waste Disposal)
- B E 487 (Watershed Modeling for Water Quality Design)
- CH E 350 (Process Heat Transfer)
- CH E 432 (Petroleum Processing)
- CH E 438 (Bioprocess Engineering)
- CH E 442 (Polymer Processing Technology)
- C E 447 (Structural Analysis by Matrix Methods)
- C E 461 (Water-resource Engineering)
- C E 462 (Open Channel Hydraulics)
- C E 475 (Water Quality Chemistry)
- C E 479 (Environmental Microbiology for Engineers)
- CMPEN 416 (Digital Integrated Circuits)
- CMPEN 417 (Digital Design Using Field Programmable Devices)
- CMPEN 431 (Introduction to Computer Architecture)
- CMPEN 441 (Operating Systems)
- CMPEN 454 (Fundamentals of Computer Vision)
- CMPEN 455 (Digital Image Processing)
- CMPEN 461 (Communication Networks)
- CMPEN 471 (Logical Design of Digital Systems)
- CMPEN 472 (Microprocessors and Embedded Systems)
- CMPEN 475 (Functional Verification)
- CMPSC 402 (UNIX and C)
- CMPSC 421 (Net-centric Computing)
- CMPSC 426 (Object-oriented Design)
- CMPSC 428 (Programming in Ada)
- CMPSC 430 (Database Design)
- CMPSC 431W (Database Management Systems)
- CMPSC 436 (Communications and Networking)
- CMPSC 438 (Computer Network Architecture and Programming)
- CMPSC 441 (Artificial Intelligence)
- CMPSC 442 (Artificial Intelligence)
- CMPSC 448 (Machine Learning and Algorithmic AI)
- CMPSC 450 (Concurrent Scientific Programming)
- CMPSC 456 (Introduction to Numerical Analysis II)
- CMPSC 457 (Computer Graphics Algorithms)
- CMPSC 458 (Fundamentals of Computer Graphics)
- CMPSC 459 (Scientific Visualization)
- CMPSC 461 (Programming Language Concepts)
- CMPSC 462 (Data Structures)
- CMPSC 463 (Design and Analysis of Algorithms)
- CMPSC 464 (Introduction to the Theory of Computation)
- CMPSC 465 (Data Structures and Algorithms)
- CMPSC 467 (Factorization and Primality Testing)
- CMPSC 469 (Formal Languages with Applications)
- CMPSC 471 (Introduction to Compiler Construction)
- CMPSC 473 (Operating Systems Design & Construction)
- CMPSC 474 (Operating System & Systems Programming)

- CMPSC 479 (Language Translation)
- E E 413 (Power Electronics)
- E E 416 (Digital Integrated Circuits)
- E E 417 (Digital Design Using Field Programmable Devices)
- E E 420 (Electro-optics: Principles and Devices)
- E E 422 (Optical Engineering Laboratory)
- E E 424 (Principles and Applications of Lasers)
- E E 430 (Principles of Electromagnetic Fields)
- E E 432 (RF and Microwave Engineering)
- E E 438 (Antenna Engineering)
- E E 439 (Radiowave Propagation in Communications)
- E E 441 (Semiconductor Integrated Circuit Technology)
- E E 442 (Solid State Devices)
- E E 450 (Signal and Image Processing)
- E E 453 (Fundamentals of Digital Signal Processing)
- E E 454 (Fundamentals of Computer Vision)
- E E 455 (An Introduction to Digital Image Processing)
- E E 456 (Introduction to Neural Networks)
- E E 458 (Digital Image Processing and Computer Vision)
- E E 460 (Communication Systems II)
- E E 461 (Communications I)
- E E 471 (Introduction to Plasmas)
- E E 472 (Space Astronomy and Introduction to Space Science)
- E E 474 (Satellite Communications Systems)
- E E 477 (Fundamentals of Remote Sensing Systems)
- E E 481 (Control Systems)
- E E 483 (Introduction to Automation and Robotics Systems)
- E E 484 (Control System Design)
- EGEE 411 (Energy Science and Engineering Lab)
- EGEE 412 (Green Engineering & Environmental Compliance)
- EGEE 420 (Hydrogen and Fuel Cells)
- EGEE 430 (Introduction to Combustion)
- EGEE 433 (Physical Processes in Energy Engineering)
- EGEE 436 (Modern Thermodynamics for Energy Systems)
- EGEE 437 (Design of Solar Energy Conversion Systems)
- EGEE 438 (Wind and Hydropower Energy Conversion)
- EGEE 441 (Electrochemical Engineering Fundamentals)
- EGEE 451 (Energy Conversion Processes)
- EGEE 455 (Materials for Energy Applications)
- EGEE 456 (Introduction to Neural Networks)
- EGEE 470 (Air Pollutants from Combustion Sources)
- EME 407 (Electrochemical Energy Storage)
- ENGR 421 (Materials Properties Measurements II)
- ENGR 450 (Materials Design and Applications)
- EDSGN 401 (Engineering Systems Design)
- EDSGN 452 (Projects in Humanitarian Engineering)
- EDSGN 479 (Human Centered Product Design and Innovation)
- E MCH 400 (Advanced Strength of Materials and Design)
- E MCH 402 (Applied and Experimental Stress Analysis)
- E MCH 403 (Strength Design in Materials and Structures)
- E MCH 409 (Advanced Mechanics)
- **E MCH 416H** (Failure and Failure Analysis of Solids)
- E MCH 440 (Nondestructive Evaluation of Flaws)
- E MCH 446 (Mechanics of Viscoelastic Materials)
- E MCH 461 (Finite Elements in Engineering)
- E MCH 470 (Analysis and Design in Vibration Engineering)
- E MCH 471 (Engineering Composite Materials)
- E MCH 473 (Composites Processing)
- ENGR 486 + 487 (Business Opportunities in Endineering + The Business Plan)
- E SC 400H (Electromagnetic Fields)
- E SC 417 (Electrical and Magnetic Properties)
- E SC 419 (Electronic Properties and Applications of Materials)
- E SC 445 (Semiconductor Optoelectronic Devices)
- E SC 450 (Synthesis and Processing of Electronic and Photonic Materials)
- E SC 455 (Electrochemical Methods Engineering and Corrosion Science)
- E SC 456 (Introduction to Neural Networks)
- E SC 460M/W (Multidisciplinary Design Project)
- E SC 475 (Particulate Materials Processing)
- E SC 481 (Elements of Nano/Micro-electromechanical Systems Processing and Design)
- E SC 482 (Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics)
- E SC 483 (Simulation and Design of Nanostructures)
- E SC 484 (Biologically Inspired Nanomaterials)
- ENVE 417 (Hydraulic Design)
- ENVE 424 (Solid Waste Management)
- ENVE 470 (Air Quality)
- ENVSE 404W (Surface and Interfacial Phenomena in Environmental Systems)
- ENVSE 440 (Industrial Ventilation for Contaminant Control)
- ENVSE 470 (Systems Safety and Risk Engineering)
- I E 405 (Deterministic Models in Operations Research)
- I E 408 (Cognitive Work Design)
- I E 418 (Human/Computer Interface Design)
- I E 419 (Work Design - Productivity and Safety)
- I E 424 (Process Quality Engineering)
- I E 425 (Stochastic Models in Operations Research)
- I E 428 (Metal Casting)
- I E 433 (Regression Analysis and Design of Experiments)

- I E 434 (Statistical Quality Control)
- I E 436 (Six Sigma Methodology)
- I E 454 (Applied Decision Analysis)
- I E 456 (Industrial Robot Applications)
- I E 460 (Service Systems Engineering)
- I E 462 (Introduction to Expert Systems)
- I E 463 (Computer Aided Design and Manufacturing)
- I E 464 (Assembly of Printed Circuit Boards)
- I E 466 (Concurrent Engineering)
- I E 467 (Facility Layout and Material Handling)
- I E 468 (Optimization Modeling and Methods)
- I E 470 (Manufacturing System Design and Analysis)
- I E 477 (Computer Control of Manufacturing Machines and Processes)
- I E 478 (Retail Services Engineering)
- I E 479 (Human Centered Product Design and Innovation)
- MATSE 400 (Crystal Chemistry)
- MATSE 402 (Materials Process Kinetics)
- MATSE 403 (Biomedical Materials)
- MATSE 404 (Surfaces and the Biological Response to Materials)
- MATSE 409 (Nuclear Materials)
- MATSE 410 (Phase Relations in Materials Systems)
- MATSE 411 (Processing of Ceramics)
- MATSE 412 (Thermal Properties of Materials)
- MATSE 413 (Solid-State Materials)
- MATSE 417 (Electrical and Magnetic Properties)
- MATSE 421 (Corrosion Engineering)
- MATSE 422 (Thermochemical Processing)
- MATSE 426 (Aqueous Processing)
- MATSE 430 (Materials Characterization)
- MATSE 435 (Optical Properties of Materials)
- MATSE 436 (Mechanical Properties of Materials)
- MATSE 440 (Nondestructive Evaluation of Flaws)
- MATSE 441 (Polymeric Materials)
- MATSE 443 (Introduction to the Materials Science of Polymers)
- MATSE 444 (Solid State Properties of Polymeric Materials)
- MATSE 445 (Thermodynamics, Microstructure, and Characterization of Polymers)
- MATSE 446 (Mechanical and Electrical Properties of Polymers and Composities)
- MATSE 447 (Rheology and Processing of Polymers)
- MATSE 448 (Polymer Processing Technology)
- MATSE 450 (Synthesis and Processing of Electronic and Photonic Materials)
- MATSE 455 (Properties and Characterization of Electronic and Photonic Materials)
- MATSE 475 (Particulate Materials Processing)
- MATSE 483 (Simulation and Design of Nanostructures)
- M E 400 (Thermodynamics of Propulsion and Power Systems)
- M E 401 (Refrigeration and Air Conditioning)
- M E 402 (Power Plants)
- M E 403 (Polymer Electrolyte Fuel Cell Engines)
- M E 404 (Gas Turbines)
- M E 405 (Indoor Air Quality Engineering)
- M E 406 (Introduction to Statistical Thermodynamics)
- M E 408 (Energy Systems)
- M E 410 (Heat Transfer)
- M E 411 (Heat-Exchanger Design)
- M E 420 (Compressible Flow)
- M E 421 (Viscous Flow Analysis and Computation)
- M E 422 Principles of Turbomachinery)
- M E 427 (Incompressible Aerodynamics)
- M E 428 (Applied Computational Fluid Dynamics)
- M E 430 (Introduction to Combustion)
- M E 431 (Internal Combustion Engines)
- M E 432 (Rocket Propulsion)
- M E 433 (Fundamentals of Air Pollution)
- M E 444 (Engineering Optimization)
- M E 446 (Reliability and Risk Concepts in Design)
- M E 448 (Engineering Design Concepts)
- M E 456 (Industrial Robot Applications)
- M E 460 (Advanced Machine Design Problems)
- M E 461 (Finite Elements in Engineering)
- M E 462 (Lubrication in Machine Design)
- M E 468 (Engineering for Manufacturing)
- M E 470 (Analysis and Design in Vibration Engineering)
- M E 471 (Noise Control in Machinery)
- M E 480 (Mechanism Design and Analysis)
- M E 481 (Introduction to Computer-Aided Analysis of Machine Dynamics)
- NUC E 401 (Introduction to Nuclear Engineering)
- NUC E 405 (Advanced Reactor Design)
- NUC E 406 (Introduction to Statistical Thermodynamics)
- NUC E 408 (Radiation Shielding)
- NUC E 409 (Nuclear Materials)
- NUC E 420 (Radiological Safety)
- NUC E 428 (Radioactive Waste Control)
- NUC E 430 (Design Principles of Reactor Systems)
- NUC E 446 (Reliability and Risk Concepts in Design)
- NUC E 450 (Radiation Detection and Measurement)
- NUC E 451 (Experiments in Reactor Physics)
- P N G 450 (Drilling Design and Production Engineering)
- P N G 475 (Petroleum Engineering Design)
- P N G 480 (Production Process Engineering)

Other Courses (select 0–2 courses)

- CHEM 212 (Organic Chemistry II)
- CHEM 402 (Chemistry in the Environment)
- CHEM 406 (Nuclear and Radiochemistry)
- CHEM 452 (Physical Chemistry - Quantum Chemistry)
- CHEM 466 (Molecular Thermodynamics)
- CHEM 472 (General Biochemistry I)
- F SC 431 (The Chemistry of Fuels)
- MATH 419 (Theoretical Mechanics)
- MATH 450 (Mathematical Modeling)
- MATH 461 (Theoretical Mechanics)
- METEO 421 (Atmospheric Dynamics)
- METEO 436 (Radiation and Climate)
- METEO 477 (Fundamentals of Remote Sensing Systems)
- PHYS 406 (Subatomic Physics)
- PHYS 410 (Introduction to Quantum Mechanics I)
- PHYS 411 (Introduction to Quantum Mechanics II)
- PHYS 412 (Solid State Physics I)
- PHYS 414 (Solid State Physics)
- PHYS 419 (Theoretical Mechanics)
- PHYS 421W (Research Methods in Physics)
- PHYS 443 (Intermediate Acoustics)
- PHYS 457W (Experimental Physics)
- PHYS 458 (Intermediate Optics)
- PHYS 461 (Theoretical Mechanics)
- PHYS 462 (Applications of Physics in Medicine)
- PHYS 472 (Elements of Nuclear Physics and its Applications to Medical Imaging and Treatments)

Only one of the following may be used to fulfill a technical elective requirement

ENGR 295 + 395 + 495 — student must complete all three co-op rotations

3 credits of coursework required for a minor — student must complete the minor

- EDSGN 4xx (Solid Works/Advanced CAD)

Exceptions for technical electives not included on this list will be considered by department petition.

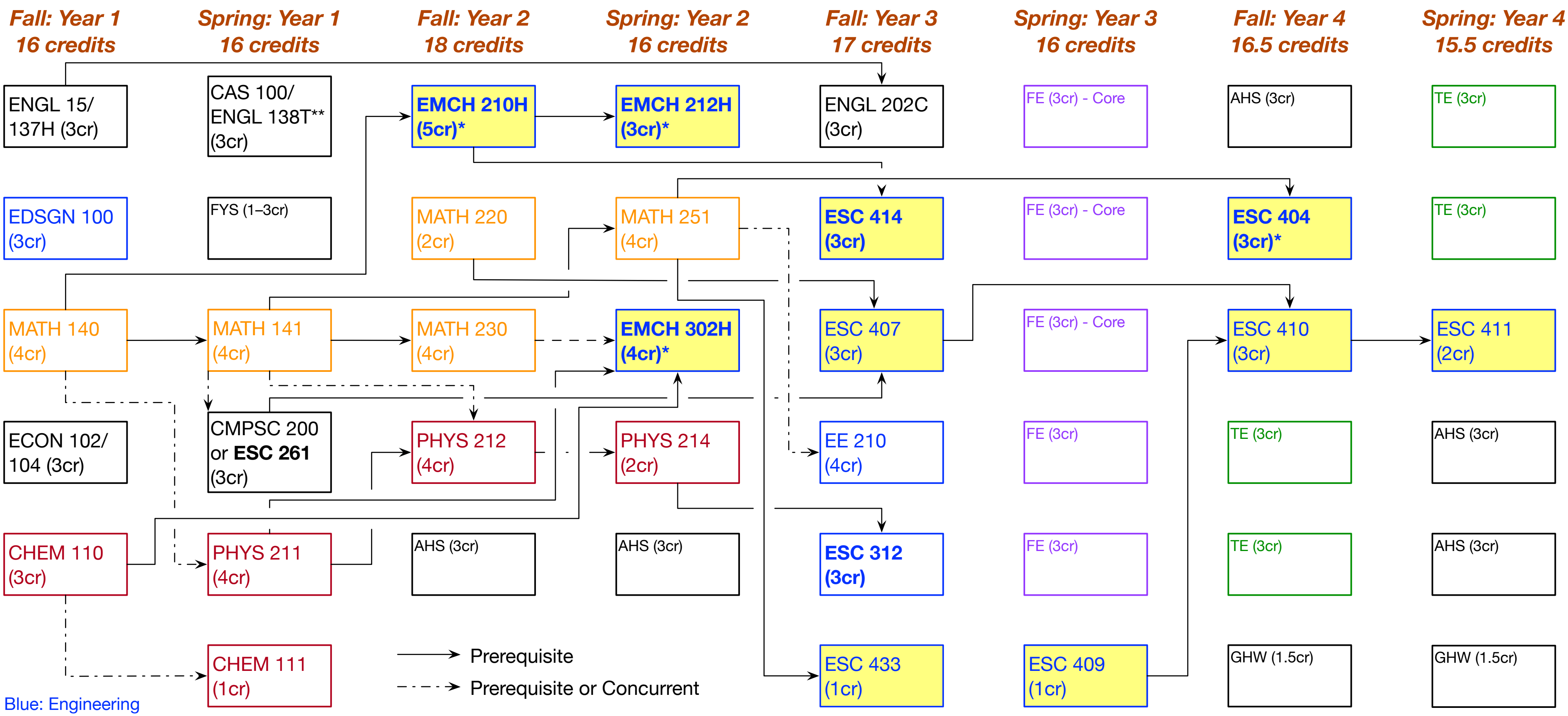
Note: Some of these courses may be enrollment controlled for students in that major. In these cases, please check with the specific department to determine their policy on letting students from other majors enroll in their courses.

Engineering Science Course Flow Charts

The following two pages show the Engineering Science Flow Charts for our curriculum plus the pre-med pathway. These flow charts serve as a guide to the sequence of courses in our program.

Engineering Science Flow Chart

Last modified: Aug 23, 2020



Blue: Engineering
Orange: Math
Red: Science
Green: Engr or Sci
Purple: Engr or Sci
Black: Gen Ed/Other

*Indicates that an alternate course is available.

**ENGL 137H is a prereq for ENGL 138T. ENGL 138T also fulfills the FYS requirement.

Boldface indicates the course is only offered that semester.

indicates honors

Foundational Electives (w/ prereqs)

Core FEs (choose 3–5)

- ☐ CHEM 112 (3cr) [Sp,Su,Fa]
  — CHEM 110
- ☐ AERSP 308 (3cr) [Sp]
  — EMCH 212, MATH 251
- ☐ EMCH 416 (3cr) [Sp]
  — EMCH 213 or EMCH 210
- ☐ ESC 400 (3cr) [Sp]
  — EE 210, MATH 250
- ☐ ESC 419 (3cr) [Sp]
  — ESC 312

Alternative FEs (choose 0–2)

Departmental list contains course in AERSP, AE, BMB, BME, BIOL, CE, CHE, CHEM, CMPEN, CMPSC, EE, ESC, EGEE, ENGR, IE, ME, MATH, MATSE, METEO, NUCE; others by petition

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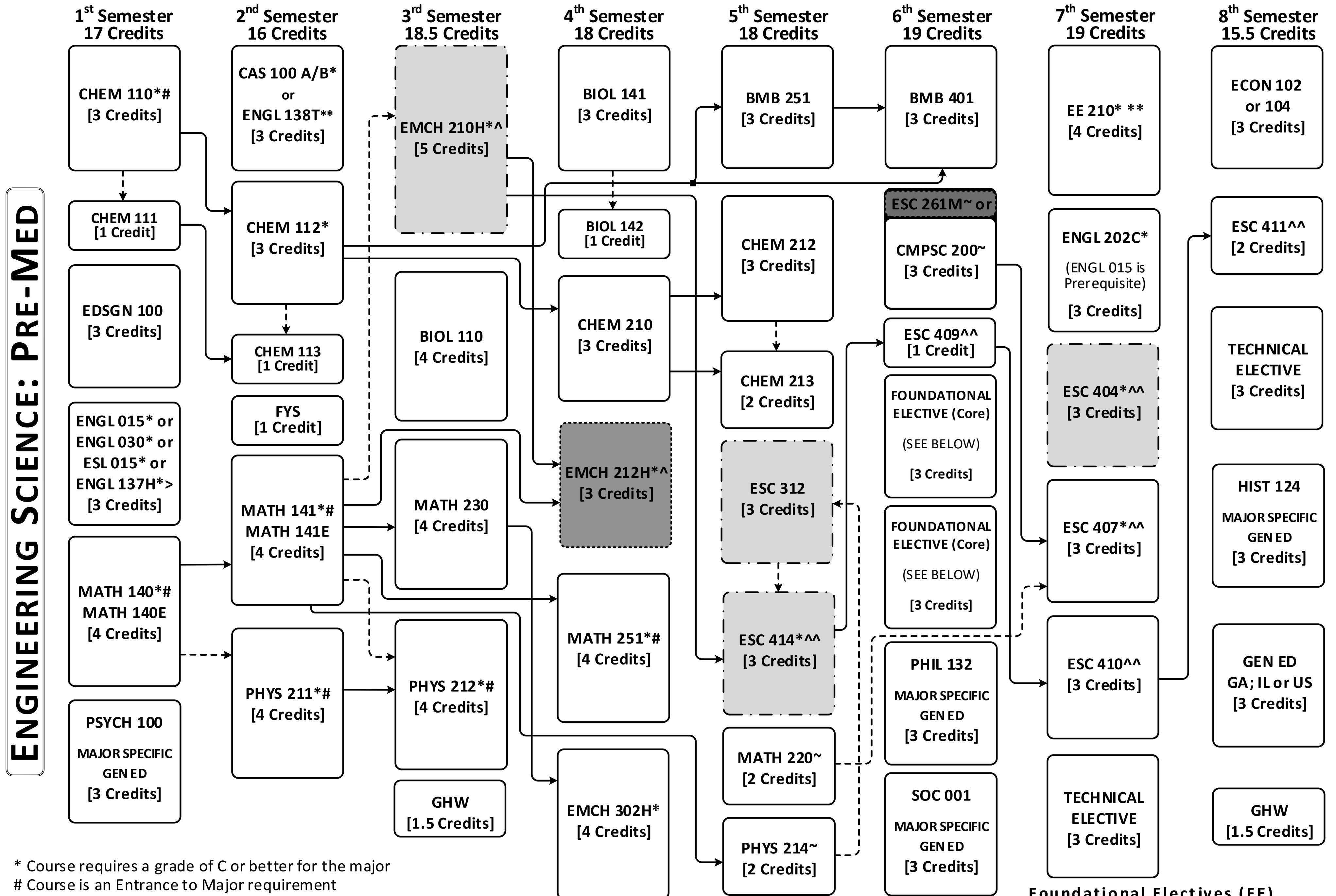
General Education (Gen Ed)

Each domain must contain at least one single domain course. Those go in this column.		The 6 credits of integrative studies should go in this column.	US Cultures (US)
Arts (GA)			Int'l Cultures (IL)
Humanities (GH)			Six credits of integrative studies are required via either 6 credits of linked (Z) or 6 credits of interdomain courses (N). Indicate these courses on the left. Applies to students starting or re-enrolling Summer 2018 or later.
Social Sciences (GS)			



* Course requires a grade of C or better for the major
\# Course is an Entrance to Major requirement
** Course is frequently honors optioned
>< ENGL 137H is a prerequisite for ENGL 138T
^ An alternate course is available the other semester
^^ Honors course
——— = Prerequisite
- - - - = Prerequisite or Concurrent

Spring Only Courses

Fall Only Courses

Foundational Electives (FE)
with prerequisites

Core (Select 3-5 Courses)		Alternative FEs
☑ CHEM 112 (3cr) - *CHEM 110*		BIOL 141
❑ AERSP 308H (3cr) [SP] - *EMCH 212, MATH 251*	❑ ESC 400H (3cr) [SP] - *EE 210, MATH 250*	CHEM 210
❑ EMCH 416H (3cr) [SP] - *EMCH 213 or 210*	❑ ESC 419 (3cr) [SP] - *ESC 312*	

Updated: 6/6/19
advising.engr.psu.edu

This is meant to support the current Suggested Academic Plan found at bulletins.psu.edu

Chapter 2: ESM Department Information

2. 1 — Statistics

ESC Majors: 69

EMCH Minors: 44

NANO Minors: 10

Graduate Students (M.S., M.ENG., Ph.D.): 153

ESM Faculty: 41

Research Laboratories and Centers: 26

2. 2 —ESM Faculty Areas of Current Research

Dinesh Agrawal, Ph.D. Professor Emeritus of Engineering Science and Mechanics; Director of Microwave Processing and Engineering Center

Andrea Arguelles, Ph.D. Assistant Professor of Engineering Science and Mechanics; Associate Professor of Acoustics: Experimental, computational, and theoretical research in the area of stress wave propagation in heterogeneous media with applications in: materials and microstructure characterization, nondestructive evaluation, effective medium modeling, biomedical ultrasound, among others.

Osama O. Awadelkarim, Ph.D. UNESCO Chair Professor of Engineering Science and Mechanics; Director of the Center for Nanotechnology Education and Utilization: Nano-fabrication; microelectronics materials/devices; power electronic devices; IC Processing; Defects in crystalline/polycrystalline semiconductor materials; Thin film transistors - active matrix liquid crystal display application; MEMS/nanofabrication.

Charles E. Bakis, Ph.D. Distinguished Professor of Engineering Science and Mechanics: Director of Composites Laboratory. Research activities center on the design, manufacturing, test, and analysis of fiber and nano-reinforced polymeric composite materials and structures.

Laura Cabrera, Associate Professor of Engineering Science and Mechanics, and Philosophy Dorothy Foehr Huck and J. Lloyd Huck Career Chair in Neuroethics: Ethical, social, and policy implications of neuroscience advances and neurotechnologies.

Huanyu Cheng, Ph.D. Assistant Professor of Engineering Science and Mechanics: Advanced Materials and Devices; Applied Mechanics and Biomechanics; Nanoscience, Bionanoscience and Engineering; Structural and Human Health Monitoring

Francesco Costanzo, Ph.D. Professor of Engineering Science and Mechanics; Professor of Mechanical Engineering; Professor of Biomedical Engineering: Continuum thermodynamics; Mechanics of thin films; Time-dependent fracture and damage mechanics of composites; Micromechanics and homogenization of inelastic composites; Computational mechanics; Thermodynamics of interfaces; Large deformations.

Joseph P. Cusumano, Ph.D. Professor of Engineering Science and Mechanics: Experimental and analytical methods in nonlinear dynamics with applications to: the dynamics and stability of solids, structures, and electromechanical devices; human movement; and machinery failure prediction.

Saptarshi Das, Ph.D. Assistant Professor of Engineering Science and Mechanics: Advanced Materials and Devices

Melik C. Demirel, Ph.D. Professor of Engineering Science and Mechanics; Llyod and Dorothy Foehr Huck Chair in Biomimetic Materials; Center for Research on Advanced Fiber Technologies Director*:* Bio-molecular materials, biosensors, protein physics, molecular modeling, computatonal materials science.

Corina Drapaca, Ph.D. Associate Professor of Engineering Science and Mechanics; brain biomechanics, continuum mechanics, mathematical medicine, computational mechanics, medical image processing, elastography, inverse problems, tumor growth.

Patrick Drew, Ph.D. Associate Professor of Engineering Science and Mechanics; Associate Professor of Biomedical Engineering: Neuroscience, neurovascular coupling.

Timothy John Eden, Ph.D. Senior Research Assosciate in Engineering Science and Mechanics; Applied Research Laboratory

Bruce Gluckman, Ph.D. Professor of Engineering Science and Mechanics; Professor of Biomedical Engineering: I am interested in the application of tools from the nonlinear dynamics community to the understanding neural activity and creating brain-machine interfaces. Ongoing work includes creating and testing neural stimulation devices for chronic use.

Gary L. Gray, Ph.D. Associate Professor of Engineering Science and Mechanics; Undergraduate Officer: Nonlinear dynamics and stability of engineering systems. Modeling of mechanical systems. Mechanics education.

Reginald Hamilton, Ph.D. Associate Professor of Engineering Science and Mechanics

Mark W. Horn, Ph.D. Professor of Engineering Science and Mechanics; Undergraduate Minors

Program and Curriculum Coordinator: Plasma etching, thin film deposition, lithography, planarization, MEMS, gas sensors, and engineered thin films

Jian Hsu, Ph.D. Professor of Engineering Science and Mechanics: Semiconductor optoelectronic devices/circuits; bioelectronic and biophotonic devices; MicroOptoElectroMechanical Systems; Molecular bioelectronic materials; Light-sensitive proteins; Polymers; Electro-optic modulators; Semiconductor lasers and detectors.

Kevin Koudela, Ph.D. Research Associate in Engineering Science and Mechanics; Applied Research Laboratory

Christopher Kube, Ph.D. Assistant Professor of Engineering Science and Mechanics; Assistant Professor of Acoustics: Broad interest in the study of ultrasound propagation and scattering in heterogeneous and microstructured materials. This interest spans a variety of material systems including metamaterials, composites, polycrystalline media, and polymeric materials with characteristics including strong property fluctuations, nonlinearity, incompressibility, and anisotropy. Applications include microstructure characterization, ultrasonic beam control, structural health assessment, and qualification of parts especially in the additive manufacturing domain.

Terence Kuzma, Instructor of Engineering Science and Mechanics; Center for Nanotechnology Education and Utlization

Akhlesh Lakhtakia, Ph.D. Evan Pugh University Professor and Charles Godfrey Binder Professor of Engineering Science and Mechanics: Sculptured thin films; Metamaterials; Nanophotonics; Nanotechnology; Electromagnetics; Composite materials; Chirality; Anisotropic and bianisotropic mediums; Bianisotropic mediums; Acoustics; Micropolar materials; Chaos and Fractals

Michael T. Lanagan, Ph.D. Professor of Engineering Science and Mechanics: Development of electronic materials for miniaturized wireless devices and electromagnetic property characterization of materials at microwave and mm-wave frequencies

Matthew Lear, Ph.D. Research Associate in Engineering Science and Mechanics; Applied Research Laboratory

Patrick M. Lenahan, Ph.D. Distinguished Professor of Engineering Science and Mechanics: Magnetic resonance, metal oxide silicon based microelectronics and nanoelectronics device physics problems, high dielectric constant oxides, silicon carbide, spin based quantum computing, homeland security related problems.

Clifford J. Lissenden, Ph.D. Professor of Engineering Science and Mechanics; Professor of Acoustics: General area of nondestructive characterization of materials using ultrasonic guided waves applicable to metals, composites, concrete, rock, and bone. I am interested in nondestructive testing and inspection, structural health monitoring, process monitoring, and cloaking structures from earthquakes.

Christine B. Masters, Ph.D. Assistant Dean for Academic Support and Global Programs, Associate Professor of Engineering Science and Mechanics: Engineering education, instructional technology, and numerical modeling.

Vincent Meunier, Ph. D., Department Head of ESM, P.B. Breneman Chair, and Professor of Engineering Science and Mechanics

Abdalla Nassar, Ph.D. Associate Research Professor of Engineering Science and Mechanics; Applied Research Laboratory; Mechanical Engineering

Ibrahim Ozbolat, Ph.D. Hartz Family Career Development Associate Professor of Engineering Science and Mechanics; Associate Professor of Biomedical Engineering: Emerging Manufacturing Processes for Materials, Tissues, and Devices

Sahin Ozdemir, Ph.D. Associate Professor of Engineering Science and Mechanics

Todd Palmer, Ph.D. Director of Center for Innovative Sintered Products and Professor of Engineering Science and Mechanics

Lucas J. Passmore, Ph.D. Associate Teaching Professor of Engineering Science and Mechanics, Undergraduate Program Coordinator

Christian Peco, Ph.D. Assistant Professor of Engineering Science and Mechanics: Interdisciplinary research that explores problems in biomechanics and materials science with the long-term objective placed on the active control of soft materials, such as lipid bilayers, to create bioinspired soft nanomachinery.

Adomas Povilianskas, M.S. Instructor of Engineering Science and Mechanics

Edward Reutzel, Ph.D. Senior Research Associate in Engineering Science and Mechanics; Applied Research Laboratory

Jacques Riviere, Ph.D. Assistant Professor of Engineering Science and Mechanics; Assistant Professor of Acoustics: Ultrasonics, geophysics, nonlinear acoustics, vibrations, nondestructive testing of materials, structural health monitoring, material characterization and damage assessment, and friction

Vyacheslav (Slava) Rotkin, Ph.D Frontier Professor Emeritus in Engineering Science and Mechanics

Joseph L. Rose, Ph.D. Paul Morrow Professorship in Engineering Design and Manufacturing: Ultrasonics, nondestructive evaluation, guided waves, wave mechanics, sensors, structural health monitoring, artificial intelligence.

Albert E. Segall Ph.D. Professor of Engineering Science and Mechanics, Graduate Programs Officer: High-temperature materials, thermal shock, and thermal Stresses; Wear; Friction; Cold-spray coatings; Realistic tribotest methods; Finite-element modeling; Failure analysis.

Parisa Shokouhi, Ph.D. Associate Professor of Engineering Science and Mechanics; Associate Professor of Acoustics: Stress wave propagation in fractured media, nondestructive evaluation (linear and nonlinear ultrasonic testing), structural health monitoring (acoustic emission), machine learning and data analytics, seismic metamaterials

Elzbieta Sikora, Ph.D. Associate Teaching Professor of Engineering Scinece and Mechanics; Graduate Programs Coordinator: Corrosion, lightweight metals, coatings, corrosion in gas and oil environments, biomaterials.

Samia Suliman, Ph.D. Associate Teaching Professor of Engineering Science and Mechanics: Electrical characterization of microelectronic devices and materials.

Judith A. Todd, Ph.D. Professor of Engineering Science and Mechanics: Laser materials interaction; far-from equilibrium solidification; non-destructive evaluation of ceramic and ceramic matrix composite materials; Creep of advanced ceramic and ceramic materials; NDE; Mechanical behavior.

Henrietta Tsosie, Ph.D, Assistant Teaching Professor in Engineering Science and Mechanics

Douglas Wolfe, Ph.D. Professor and Senior Scientist in Engineering Science and Mechanics

Yang Yang, Ph.D, Assistant Professor in Engineering Science and Mechanics: Advanced Materials and Devices; Applied Mechanics and Biomechanics; Energy Infrastructure, Storage and Devices; Nanoscience, Bionanoscience and Engineering

Cunjiang Yu, Ph.D, Dorothy Quiggle Career Development Associate Professor of Engineering Science and Mechanics; Biomedical Engineering

Sulin Zhang, Ph.D. Professor of Engineering Science and Mechanics:
Computational mechanics, nanomechanics.

2. 3 —Facilities

The Engineering Science and Mechanics (ESM) Departmental Office, most faculty, and teaching and m a n y research laboratories are housed in the *Earth-Engineering Sciences Building* on the West Campus. The ESM faculty also have laboratories in the Millennium Science Complex (MSC), Hammond Building, the Materials Research Institute (MRI) Building, the Materials Research Lab (MRL), and Research West Building. These state-of- the-art facilities are primarily created and maintained by instructional and research funding. Themes for the labs include nanofabrication, MEMS (micro electro-mechanical systems), powdered materials, ultrasonic characterization, underwater acoustics, environmental degradation, neural networking, composite materials and structures, as well as thermomechanical fatigue and failure analysis. In as much as the Engineering Science curriculum features undergraduate research through seminars, special lab course ESC 433H, research internships, and the senior research and design project, ESC students will have opportunities to work in many of these laboratories during their undergraduate years.

The ESM laboratories include:

AI/Neural Networking: AI/Chaos/ Neural Networking/Fuzzy Logic/Data Mining computer with software facilities to develop applications.

Primary and Secondary Battery Laboratory: including glove boxes, Solartron frequency analyzers, potentiostats, and cell testing facilities.

Bio-molecular Materials Laboratory: Genetic analyzer and sequencer, thermo-cycle (PCR), incubator, airflow system (class level-II), microfluidic laser system (CO2), optical microscope for visualization of cell studies, chromatography (HPLC), spectrophotometer, electrophoresis, and other small devices required for bio-molecular materials and cell level studies.

BioNEMS Laboratory: Novel nanomaterials, nanomanufacturing, and nanodevices for medical diagnosis, prevention, and treatment

Center for Innovative Sintering Products: die compaction, injection molding, hot and cold isostatic presses, wide variety of sintering and prototyping facilities, optical and electron microscopy, materials and powder characterization tools, process models and computer simulations.

Composites Manufacturing Technology Center: filament winder, pultruder, hot presses, furnaces, impact systems, flywheel testing chamber, thermal analyzer, resin transfer molder, autoclave, and loading frames for impact, high-rate, cyclic, quasi-static, and creep tests.

Computational Mechanics: rack-mount cluster for high-performance parallel computing, gigabit Ethernet, MPI software libraries, symbolic algebra and visualization software, a variety of compilers.

Corrosion/Environmental Degradation: salt fog cabinet, computer controlled and stand- alone potentiostats, alternate immersion tester, heated immersion baths, corrosion cells, class 1000 cleanroom, dual gun EB-PVD system.

Corrosion Detection and Prediction: on underground pipelines.

Dynamics/Shock/Vibration: shaker tables, non-linear simulators, high speed camera system, high stain rate hydraulic system.

XL30 ESEM Scanning Electron Microscope: wide range of magnification, EDAX X- ray system, imaging of non-conductive or even wet samples, light element analysis (such as oxygen and carbon), excellent resolution over wide depth of field

Experimental Stress Analysis: strain gage instrumentation, photoelastic test benches, Moire interferometer, quasi-static load frames.

Fourier Optics Laboratory: Optical information extraction.

Fatigue, Fracture, and Creep: tension/torsion, tension/compression, and internal pressure hydraulic systems, 3-point and 4-point bending, anticlastic bending, induction heating system, strain gage instrumentation, extensometry, creep frames.

Laser Technology: design and fabrication of semiconductor lasers, solid state lasers technology, laser ablation, pulse laser deposition of novel materials, and pump-probe detection of ultrafast phenomenon with femtosecond laser pulses.

MEMS: (micro-electronic-mechanical-systems): newest lab-stereo lithography, characterization, processing.

Microscopy/Failure Analysis: scanning electron microscope, scanning laser conformal optical microscope, metallograph.

Microwaves: vector network analyzer, shielded chamber, wave guides, anechoic chamber, tabletop freespace material characterization facility, in-situ high temperature facility.

Nanofabrication: class 10 and class 100 cleanroom, plasma and chemical film deposition tools, wet and plasma etching systems, ebeam and photo lithography, surface modification and characterization tools, light, scanning electron and atomic force microscope systems.

Non-Destructive Evaluation: ultrasonic systems, radiography, SEM, thermographic system, photoelasticity.

Optoelectronics Laboratory: focus is on development of novel optoelectronic materials and their device applications in bio/chemical sensing, optical communication and displays. Particular emphasis is placed on synthesizing low dimensional semiconductor structures such as colloidal nanocrystal quantum dots, nanowires and nanosheets and exploring their potentials by integrating them in a variety of electronic and photonic device structures.
Semiconductor Spectroscopy: electron spin resonance, spin dependent recombination, ultraviolet illuminator.

Smart Structures & Systems: pulse tube facility for underwater measurements, active vibration and noise control, wireless SAW microsensors, DSP and controllers.

Thermal Shock and Laser Machining: 500W (1.5KW peak) power CO2 laser with custom and simultaneous, dual-beam capability developed for reduced-fracture-risk methods.

Thermomechanical Processing of Materials: fabrication, heat treatment, room and high temperature deformation processing.

Thin Film Preparation: Sculptured thin films, RF and DC sputtering systems, ion assisted evaporation, plasma assisted chemical vapor deposition, FTIR spectroscopy, profilometry, deflection method of thin film stress analysis.

Tribology: Plint system, pin-on-disk, high pressure/temp system for ceramics.

Ultrasonics: scanning acoustic microscope, atomic force microscope, C-Scan, tomography, guided waves, structural health monitoring.

Wave/Materials Interactions: active coatings, transducers, chiral materials.

2. 4 —The Undergraduate Program

The College of Engineering and the Engineering Science Honors program, which is the undergraduate major in the Department of Engineering Science and Mechanics, are both highly ranked nationally. (For example, the College is ranked high nationally in the *U.S. News and World Report College Report* and the Engineering Science program has been included in the top ten programs in the *Gourman Report*). The Engineering Science curriculum is characterized by greater breadth of training in the engineering sciences than is found in traditional engineering majors. It is a broad, science-based program, with relatively uniform emphasis over all the engineering sciences for the first three years. In their senior year, students can use their technical electives in conjunction with their research and design project to pursue any particular engineering area in depth.

The engineering sciences are built on a foundation of required courses in basic science and mathematics, most of which are taught exclusively for Engineering Science students. These courses stress the basic principles underlying engineering analysis and the transferability of engineering concepts from one discipline to another. The student builds on these sequences by choosing elective courses and a senior research and design project appropriate to his or her specific field ofinterest.

It should be noted that in the Engineering Science curriculum, depth in an area is not sacrificed to obtain overall breadth. This is accomplished by (1) an array of accelerated courses (appropriate for the ESC Honors students), (2) a junior year devoted to the engineering sciences, and (3) a senior year wherein the student may choose four technical electives in an area in which to carry out the research and design project and write a senior thesis.

Engineering Science students may select minors in any area; the engineering mechanics minor and the nanotechnology minor are offered by the ESM department as a focus area of study.

The Engineering Science major offers a unique opportunity for excellent students who are interested in serving society as creative engineers. Its emphasis on a science background and interdisciplinary nature prepares students to cope with the complex, multi-faceted problems of technology in contemporary society. The many options available permit students to enrich and strengthen their background in an area of individual choice.

2. 5 —Scholastic Requirements, Honors Program

The Engineering Science major is the Honors program of the College of Engineering. The following features characterize this Honors program at Penn State:

- For admission to the Engineering Science program, a student must show unusual academic promise.

- For admission, a cumulative grade-point average of at least 3.00 is required. Faculty approval is required if the cumulative average is below 3.00.

- Students who are in the first or second year and who are considering Engineering Science as a major are encouraged to take Honors courses whenever possible. During the combined third and fourth years, without exception, no fewer than 16 Honors credits will be accepted in satisfaction of Honors degree requirements.

- Each student in the Honors program must complete a senior thesis. In Engineering Science, the report of the senior research and design project (ESC 409H, ESC 410H and 411H) serves as the senior thesis. The thesis must be typed and a final draft submitted for Department head approval by the dead-line published each semester, typically no later than three weeks before the end of classes in a semester in which the student is registered for ESC 411H. Note this is the final draft of a document that has already been approved by both the research advisor and the academic advisor. If the Department Head requests changes, a final copy of the thesis must be submitted the following week. If no changes are requested, the final draft copy will be kept by the department for archival binding. Students in the Schreyer Honors College also submit an electronic copy of the thesis. Students earning the honors diploma (see item #9 below) who are NOT in the Schreyer Honors College must submit an additional paper copy of the thesis for university library binding. Appendix D contains guidelines for the preparation of the thesis.

- Each student must pass a thesis oral examination administered by the Department Honors committee. This examination is usually taken in the semester in which the student is registered for ESC 411H of the senior year. The examination may concentrate on the senior project, or it may be broader in scope, dealing with the basic topics in the engineering sciences.

- Each student will maintain a portfolio as described in section 3.7.

- Engineering Science students must earn a minimum grade of C in the following required courses: EMCH 210H or 210 (or the combination of EMCH 211 and 213 or EMCH 211 and 213D), EMCH 212H or 212, ESC 404H, ESC 407H, and ESC 414M.

- The minimum graduation requirements for the Engineering Science major are 131 credits and a 2.50 GPA to remain in the Engineering Science major, a student must maintain a cumulative average of at least 2.50. If the average falls below 2.50, the student is expected to change to another major.

- Engineering Science seniors who have completed the requirements for graduation will be recommended for an honors diploma if they: (1) complete a satisfactory senior thesis, (2) pass the thesis oral examination, and (3) have a cumulative average of 3.33* or higher at the time of graduation.

- At the end of every semester, the chair of the curriculum committee and the Department head, in consultation with appropriate members of the faculty, review the academic record of each student enrolled in Engineering Science to determine if the level of his/her performance is in keeping with the goals and requirements of the major. Should this review identify any students whose performances are below the standards expected of Engineering Science students, the Department Head, on behalf of the Department faculty, counsels these students on the advisability of continuing in the major.

2. 6 —Student Organizations and Programs of Interest

The Department of Engineering Science and Mechanics maintains a student chapter of a professional society, the Society of Engineering Science (SES). The student chapter of SES was established at Penn State in 1972. This professional society was founded by engineers in widely divergent and interdisciplinary fields whose interests did not fall within the boundaries of traditional disciplines such as electrical or mechanical engineering. The SES student chapter should be of interest to every student in the Department. Students are encouraged to take advantage of the opportunity to benefit from both the career and social aspects of membership.

Announcements of organization officers and activities are listed on the Department website. Through a program called Summer Research Experience for Undergraduates, a limited number of sophomores and juniors may obtain 20-40 hours per week of summer employment at the University. The students will work on current research and development projects with faculty and graduate students.

A very limited number of upper level students may be chosen each semester to participate in the Teaching Interns Program. These students will be provided some financial remuneration to assist in the teaching of a lower level engineering course under the supervision and mentoring of the faculty member teaching the course. This program is designed to encourage students to consider a career involving teaching by providing some practical experience in the profession.

The College of Engineering is committed to providing opportunities and access to women and minorities. The Minority Engineering Program is responsible for recruiting and retaining under- represented minorities, and for encouraging these qualified students to pursue engineering careers. The minority Engineering Program offers advising, counseling, and tutoring services through the minority engineering student assistance center.

The Women in Engineering Program is responsible for recruiting and retaining women students. The program offers advising for women, organizes activities, and conducts research about women in engineering.

Interested students are encouraged to take advantage of the Cooperative Education program, explore the opportunity to study abroad during the junior year, or consider participation in the Integrated Undergraduate/Graduate program.

2. 7 —Scholarships and Financial Aid

Current information is available in the Office of Student Aid, 314 Shields Building, 814- 865- 6301. Financial need is an important factor in the selection criteria for most of the department's scholarships. http://www.psu.edu/studentaid/. The department also uses endowed funds to provide scholarships to Engineering Science students who demonstrate academic excellence and or particular financial need.

2. 8 —Employment Opportunities

The B.S. Honors degree in Engineering Science provides a balanced education in both the theoretical and experimental aspects of pure and applied science. Graduates are sought by many branches of industry, as well as by research and administrative agencies of the federal government. Starting salaries in past years have been among the highest for all graduates in the College of Engineering.

Among the graduates in Engineering Science over the past few years, approximately 50 percent have entered graduate schools immediately after graduation, earning advanced degrees in a range of fields from engineering to medicine and law. The others have accepted full- time industrial positions.

Most Engineering Science graduates who go on to graduate school have financial assistance in the form of a graduate assistantship. Students interested in graduate studies should see their adviser for more information.

Announcements of employment opportunities are provided to the Department on a continuing basis by the University Placement Office. These announcements are posted on the bulletin board near the Department office. Students may obtain more detailed information concerning employment opportunities at the Career Services Office in the 235 MBNA Career Services Building.

Department majors may also elect to participate in the Cooperative Engineering Education Program, which offers the opportunity to experience engineering as it is actually practiced. Interested students should contact the Departmental Co-op coordinator (see Appendix A for more information).

The following are two websites that contain extensive listings of employment opportunities that all students should find useful:

http://www.engr.psu.edu/coop/

http://www.sa.psu.edu/career/joblink.shtml

Chapter 3: Advising and Student Portfolio

3. 1 —Advising and How it Functions

Each student is assigned an academic adviser and must meet with the adviser during the first week of each semester to evaluate his/her program of courses, to plan an overall program of study, and to update and discuss the student portfolio. The adviser must approve the student's program plans and any modifications to the requirements of the major. In the event that the adviser is not available for initial contact, the student should see the Assistant for Undergraduate Student Affairs, Sarah Jones, in Room 212 Earth-Engineering Sciences Building (865-4523), for help in making contact with an adviser.

The adviser also serves as a counselor, and may be consulted about any problem, whether it is academic or personal. As the student approaches graduation, the adviser can provide helpful information about employment opportunities and graduate schools.

3. 2 —Conferences With Your Adviser

At the appropriate times each semester, you must meet with your adviser to discuss your current status and portfolio (during the first week of the semester) and to arrange your preregistration for the following semester (during the latter part of the semester). Other meetings with your adviser are encouraged, as appropriate for your situation. The preregistration period is announced in each semester's *Schedule of Classes* or is available on line at https://lionpath.psu.edu.

3. 3 —Petitions

All exceptions to the Engineering Science curriculum, as described herein, must be approved by filing a petition. It is the responsibility of the student, in consultation with the academic adviser, to properly prepare a College petition which accurately but succinctly describes what the request is about and provides the justification for such an exception. Petitions are now submitted online using the COE e-Petition System. You can access the COE e-Petition online petition form on the COE website at coursesub.psu.edu.

3. 4 —Academic Integrity

The Department of Engineering Science and Mechanics at the Pennsylvania State University considers academic training to be apprenticeship for practice in the professions. Students are expected to demonstrate a code of moral integrity and ethical standards commensurate with the high expectations that society places upon professional practice. Accordingly, it is the policy of the department to maintain the highest standard of academic honesty and integrity.

Academic dishonesty includes, but is not limited to, cheating, copying on tests, plagiarizing, acts of aiding or abetting, unauthorized possession of materials, tampering with work, ghosting, altering examinations and theft of any property (hardware, software, lab equipment and supplies, intellectual property, etc.). Students are encouraged to report incidents of academic dishonesty to their instructors in order to promote a fair academic climate and equal opportunity learning environment.

A student charged with academic dishonesty will be given oral or written notice of the charge by the instructor. A student contesting such a charge may seek redress through informal discussions with the instructor(s), department head or college dean. If the instructor believes that the infraction is sufficiently serious to warrant referral to the Office of Conduct Standards, or if the instructor awards a final grade of F in the course because of the infraction, the student and instructor will be afforded formal due process procedures governed by Penn State Senate Policy 49-20. Policy 49-20 and procedures can be found in the document "Policy and Rules for Students" issued annually by the Senate Office and available through each student's home department or college dean's office. Academic Integrity policy information can also be found on the web at https://advising.engr.psu.edu/student-resources/academic-integrity.aspx.

3. 5 —Student's Academic File

A file is established for each student who enters the Engineering Science curriculum. This file contains the following:

- a curriculum checksheet for recording the courses completed
- copies of the undergraduate transcript
- copies of the various registrations, preregistrations, and degree audits
- records of changes, petitions, etc.
- other, such as co-op reports
- This file is an official Department record and is retained by the Department.

3. 6 —Adviser's Checksheet

To graduate, each student must satisfactorily complete all Department, College and University requirements. To keep track of progress, a checksheet of course work completed is maintained by each adviser, and it is suggested that students maintain a similar sheet for their own records.

The curriculum and/or College requirements are sometimes changed and the checksheets are revised accordingly. The proper checksheet will be furnished by each adviser. (See *Appendix E* for a sample checksheet). When regulations are changed, a student has the option of following the new regulations, if they are to his/her advantage, or of continuing to follow those that were in effect at the time he/she matriculated.

3. 7 —Student Portfolio

There is a national trend in education to create, maintain, and utilize portfolios for engineering students. Although this has been an established practice of Art, Architecture, Advertising and other professionally oriented disciplines, it is somewhat new to Engineering. The primary purpose is the collection of one's academic and professional accomplishments, which provides hard evidence of the student's progression toward achieving professional level quality in their activities.

The Engineering Science Portfolio serves three main purposes:

- Department ABET Accreditation
- Student Interview Preparation
- Enhanced Faculty Recommendation letters

As you may know, Engineering Science is an accredited engineering program as determined by the Accreditation Board of Engineering and Technology programs (ABET). To obtain/keep this accreditation, the department sets specific goals and objectives for its graduates then gathers information to demonstrate that graduates of the program are meeting these goals and objectives. One way the department measures achievement of some of these goals is through evaluation of the students portfolios.

Many previous Engineering Science graduates have indicated that the act of preparing their student portfolio made them much more aware of the skills they had already gained during their time at Penn State as well as identifying other skills they wished to enhance before leaving Penn State. Awareness of skills they wished to develop (such as leadership and team work) caused them to join student organizations or seek out industrial summer opportunities during their junior and senior years. Awareness of skills they had already developed made these students much more articulate in job interviews when asked questions such as, "What kind of design experiences have you had at Penn State?"

Just about every student needs some type of recommendation letter (for award nominations, internship or graduate school applications) before they graduate. While the faculty that you ask for these recommendation letters may know you from class and know of some of your academic achievements, they may not know of your extracurricular, summer work, or study abroad experiences. A detailed student portfolio is a great way for a faculty member to become aware of these extra experiences that can turn a good, general recommendation letter into an outstanding, high personal recommendation.

You should begin building your portfolio as soon as you have decided to major in Engineering Science. Begin by reviewing the general portfolio guidelines. Then each semester you should revisit and revise your portfolio, including new items to show skills gained and obstacles overcome, reflecting on where you've been so far and where you think you are headed. To help you with this process, see the year-by-year suggestions for portfolio development. If you are joining ESC as a 1st or 2nd year student, start at the beginning. If you are joining ESC as a junior, start by going back to the 1st or 2nd year suggestions. It is also helpful when you meet with your advisor each semester to not only discuss your academic progress but also your portfolio development.

Have fun, be creative, and most of all, be PROUD! Upon graduation this portfolio will represent a culmination of your experiences here at Penn State, both inside and outside the classroom. You will be amazed when you get there just how far you've come and how much you've changed.

Please review Appendix G for more information on the Portfolio Contents.

3. 8 —Research and Design Project

Design in the Engineering Science curriculum has a broad interpretation. For Engineering Science faculty and students, design is a creative and iterative process that encompasses systems, components and processes related to, for example, material, biological, chemical, mechanical and electrical systems. Within these systems, design is performed at length scales ranging from nanometers (the atomic level) to tens of meters (the length scales associated with our everyday experiences). The tools used for design include mathematical models (their development and iterative refinement), algorithms (of all sorts), computer simulations, experimentation and prototyping. These tools are integrated to achieve the objective of our Senior Research and Design Project.

Our Senior Capstone Research and Design Project, which culminates in an oral presentation and a written thesis, incorporates design in a variety of ways befitting our inter-disciplinary department. Engineering Science students participate in projects in all engineering disciplines and employ design principles before, during, and after analysis, experimentation and/or simulation. The resulting designs of systems, components or processes are then tested and refined by changing material, geometric, stochastic or other parameters, as required. The design is often not a machine component or a bridge, but may be a new experimental process, nanoscale device, or computer code for the modeling and/or analysis of an engineering system or process. Computer programs, written initially to analyze, are frequently rewritten to function as design tools. As appropriate, knowledge of physics, chemistry, mathematics, mechanics, materials science, etc., is harnessed along with the iterative nature of design to complete an independent research project, within a team-based environment, in a timely manner.

Chapter 4: Department and University Procedures

4. 1 —Schedule Change, Drop or Add a Course

A student may add a course to his or her schedule during the course's Add Period. This period begins on the first day of classes for the semester and ends one (1) calendar day after the end of the Drop period (see Policy 34-89). A student may add a course after the Add Period ends only with written permission of the course instructor.

A student may drop a course without academic penalty during the Course Drop period. If the duration of the course is equal to the duration of the semester, this period is the first six (6) calendar days of either the fall or spring semester, beginning midnight on the first day of class. For all other courses (those not equal in duration to a semester of which they are part and all courses offered in the summer), the duration of the Drop Period is calculated by multiplying six (6) days by the duration of the course (in weeks) divided by fifteen (15) weeks, and then rounding up to the next higher whole number of days. For example, a 6-week course would have a drop period of 3 calendar days (6 days *6 weeks / 15 weeks equals 2.4 days, rounded up to 3 days.)

There is no limit to the number of courses/credits that can be dropped during this period and courses dropped during this period do not show up on the student's academic record.

The Late Drop period for a course begins with the first calendar day after the Course Drop period and ends on the day when 80 percent of the duration of the course is attained. During the Late Drop period, the student may drop a course (Late Drop), and a notation (Policy 48-20) will be entered on the student's academic record.

A student may not drop or late drop the last/only course on his/her schedule. Dropping or late dropping the last/only course must be done through a withdrawal (Policy 56-30).

Each individual course may be taken a maximum of three times. This includes late drops and grades that are not sufficiently high. A petition must be filed to take a course a fourth time.

A fee will be charged for each change of schedule filed after the Late Drop period begins.

4. 2 —Satisfactory/Unsatisfactory Grading System

With the exceptions of ENGR 295, 395, 495, Engineering Science students are not permitted to use the satisfactory/unsatisfactory system to satisfy graduation requirements.

4. 3 —Schedules

Standard Schedule

A student enrolled in the College is expected to take the prescribed courses of his/her major in accordance with the outline published in the *Undergraduate Bulletin*. A standard or normal schedule, as indicated by these outlines, includes 12 to 19 credits per semester.

Heavy Schedule (Maximum Credit Load)

Students are strongly urged to consult with their adviser before registering for any credit course regardless of delivery system. No student shall be permitted to be enrolled for more than a typical credit load (see Senate Policy 34-52) in any one semester by all delivery systems without consultation with the student's academic adviser.

At Commonwealth Campuses the student must get the signature of the dean's representative from the College of Engineering.

Minimum Schedule

A student carrying a schedule with fewer than 12 credits is classified as a part-time student (see Senate Policy 34-53).

Light Schedule

In cases of illness or other extenuating circumstances that justify the action, a student may be permitted to drop one or more courses (but not after the 13th week) and continue in the College with a light schedule. If the schedule then has fewer than 12 credits, he/she will be reclassified as a part-time student.

Chapter 5: General Education Requirements

The baccalaureate degree General Education program consists of 45 credits that are distributed among three General Education components:

- foundations courses in writing, speaking and quantification (15 credits)
- knowledge Domains in the Arts, Humanities, Natural Sciences, Social and Behavioral Sciences, and Health and Wellness (30 credits)
- integrative Studies that bridges commonality and intersections between the Knowledge Domains

A summary of the applicable attributes to determine if a course satisfies a requirement is available on the University Course Description page. The keystone symbol appears by the title of any course that is designated as a General Education course. Program requirements that may also satisfy General Education requirements vary for each program and is detailed on each degree requirements page.

Students whose academic majors are in the areas of natural sciences, arts, humanities, and social and behavioral sciences may not meet the General Education Knowledge Domains components by taking courses in the department or program identical to that of the academic major. All General Education courses are to help students explore and integrate information beyond the special focuses of their majors.

The General Education requirements for students who enrolled at Penn State prior to Summer 2018 can be found in the Archive.

In the College of Engineering, and specifically for the Engineering Science major, theGeneral Education requirements are met as follows:

Skills (18 credits required)

- Writing/Speaking (12 credits) ENGL 015 or 030. ENGL 202C CAS 100A/B

- Writing Intensive course (ESC 261M or ESC 414M)

- Quantification (6 credits required) MATH 140 and MATH 141

- Health and Physical Activity (3 credits required)

Choose a course or courses totaling three credits with the suffixes GHA or GPE or GHW to satisfy this requirement.

Distribution Component (28 credits required)

- Natural Sciences (9 credits) CHEM 110, PHYS 211, PHYS 212
- Arts (6 credits of courses designated GA)
- Humanities (6 credits designated GH)
- Social and Behavioral Sciences (6 credits of courses designated GS)
- First-Year Seminar (1 credit-any University course designated FYS)

**Please note: These are the requirements for students who have entered the university prior to the Summer 2018 semester. If you have entered the university during or after the Summer 2018 semester, please refer to https://bulletins.psu.edu/undergraduate/general-education/baccalaureate-degree-general-education-program/.

5. 1 —Arts, Humanities, and the Social and Behavioral Sciences

A 3-credit economics course is required by every engineering major. The Engineering Science and Mechanics Department will accept ECON 102, or 104. A student having passed an engineering economics course need not take an ECON course, but must still complete 18 credits in the Arts, Humanities, and the Social and Behavioral Sciences.

In consultation with the adviser, a student may develop a sequence of 9 credits in either the Arts, Humanities, or Social and Behavioral Sciences by substituting 3 credits from one of the other two areas not in the student's major field of study. A petition to this effect must be filed with the ESM Department.

A petition must be approved by the Dean before the student is permitted to take any course which is not listed in the booklet, "General Education in the Curriculum," to meet the General Education requirements.

A language course at the 12th credit level or higher can be substituted for 3 credits or Arts, Humanities, or Social Science requirements. Note: if this substitution is made, it cannot be the ONLY course in a category (i.e. it cannot be substituted for the 3 credit category in a 3-6-9 credit sequence of courses). Beginning language courses at Penn State are 4 credits each, so the 12th credit level would be a level III course (Span 003, Italian 003, French 003, etc.). If a student intends to take a language course elsewhere, he/she should consult with an adviser first, as the 12th credit level may be defined differently at other institutions.

5. 2 —Writing Across the Curriculum

As part of the baccalaureate degree program general education requirements, students are required to complete at least 3 credits of a writing-intensive course (Writing Across the Curriculum requirement) prior to graduation. Engineering Science students fulfill this requirement by completing ESC 261M or ESC 414M. Note: the M suffix signifies both a Writing Across the Curriculum requirement and an Honors course.

5. 3 —U.S. and International Cultures Requirement

All baccalaureate degree students must take at least one 3-credit United States Cultures course and one 3-credit International Cultures course. The approved courses have the designations US and IL respectively (formerly GI). Students should make sure that these US and IL courses also fulfill one of the GA, GH, or GS requirements to avoid having to take an extra course. Students with life experiences which meet the spirit of the International requirement, such as study abroad, some internships, and working in the Peace Corps, may petition to have this count as their IL requirement.

5. 4 —Other

Substitution of ENGL 202B for ENGL 202C. Students who entered the University with Advanced Standing, including credit for ENGL 202B (Writing in the Humanities) or students who changed their major to the College of Engineering having already taken ENGL 202B, may petition to substitute ENGL 202B for ENGL 202C (Technical Writing).

Students may count up to 3 ROTC credits toward AHS requirements (section 5.1) and up to 3 ROTC credits as departmental technical electives.

Chapter 6: Schedule of Course Offerings*

EMCH Course	Fall	Spring	Summer
EMCH 210	•	•	
EMCH 210H	•		
EMCH 211	•	•	•
EMCH 212	•	•	•
EMCH 212H		•	
EMCH 213	•	•	•
EMCH 296	•	•	
EMCH 302H		•	
EMCH 315	•	•	•
EMCH 316	•	•	
EMCH 400	•		
EMCH 402		•	
EMCH 403		•	
EMCH 416		•	
EMCH 440	•		
EMCH 446		•	
EMCH 461	•		
EMCH 470		•	
EMCH 471	•		
EMCH 473		•	
EMCH 496	•	•	•
EMCH 497	•		

ESC Course	Fall	Spring	Summer
ESC 97	•	•	
ESC 120	•		
ESC 121	•		
ESC 211		•	•
ESC 212		•	•
ESC 213		•	•
ESC 214		•	•
ESC 215		•	•
ESC 216		•	•
ESC 261		•	
ESC 296	•	•	•
ESC 312	•		
ESC 313		•	
ESC 400		•	
ESC 404	•		
ESC 407	•		
ESC 409	•	•	
ESC 410	•	•	•
ESC 411	•	•	•
ESC 412	•		
ESC 414	•		
ESC 417		•	
ESC 419		•	
ESC 433	•	•	
ESC 445		•	
ESC 450	•		
ESC 460M	•		
ESC 460W	•		
ESC 481	•		
ESC 482	•	•	
ESC 484		•	
ESC 496	•	•	•
ESC 497	•	•	•

*Note, not all courses each semester are guaranteed to run for reasons varying from low enrollment numbers to no instructor available due to illness, sabbatical, etc.

Chapter 7: Special Academic Programs

The University offers many special academic programs including the Cooperative Education program, the Integrated Undergraduate/Graduate program, the Study Abroad program, the Schreyer Honors College, the Concurrent Majors Program, and a variety of minor specialization programs (the Engineering Science and Mechanics Department offers a minor in Engineering Mechanics). Appendices A, B, and C of this guide offer additional information of the Co-op program, the Integrated Undergraduate/Graduate program, and the EMCH minor, respectively. Before entering any special program, students should first refer to the current Penn State *Baccalaureate Degree Programs Bulletin* and consult with their academic advisers.

APPENDIX A: The Engineering Science Co-op Program

Description of the Program

The Cooperative Education Program of the College of Engineering was developed to provide an opportunity for students to obtain one full year of work experience while they earn their undergraduate degrees. The program has many benefits for students, including exposure to real work situations, on-the-job training, and earned salary that can be used toward tuition and living expenses. In general, the work experience will be divided into three segments: a fall semester, a spring semester and a summer session. Students participating in the program will typically graduate in December of the fifth academic year, thus completing the degree program in four and one-half years.

Sources of Information on the Program:

- Booklet – *Penn State Engineering Co-op Student Handbook*
- Website http://www.engr.psu.edu/coop/

Application and Admission to the Program:

- Eligibility: Students must seek to enter the program by the end of the *sophomore* year. A declaration of major should have been made prior to entry into the program.

- Admission requirements: A student intending to enter the program must be in good standing. However, some of the participating employers may have their own standards with regard to the minimum GPA students must have to be considered for placements with their company. U.S. citizenship may be required for some positions.

- Application procedure: Follow the detailed set of instructions in the above referenced *Co-op Student Handbook*.

- Staff support (people to help you):

  - ✓ College Co-op Program Director 117 Hammond Bldg. (863-1032).

  - ✓ Engineering Science Co-op Coordinator: Dr. Lucas Passmore
    212 Earth-Engineering Sciences Building. (867-5409).

<u>The Eight Steps</u>

The *Co-op Student Handbook* lists the following eight steps (Understanding Cooperative Education, Participation in the Engineering Cooperative Education Program, Creating a Resume, Job Searching with the Co-op Office, the Interview Process, Selecting and Accepting a Position, Preparing to Go on Co-op, and Returning from Your Co-op Assignment) that must be understood and followed in order for the co-op experience to be successful. It is the responsibility of every co-op student to know and abide by these regulations. These steps also discuss some very basic concerns of students such as canceling dorm contracts, financial aid, and registering for the next semester while on co-op assignment.

After Each Segment of the Work Experience

Evaluation and Reporting: Near the end of each work experience, a Students Evaluation of Employer and Co-op Program form must be completed and submitted to the Co-op office. Furthermore, a term report on the work experience must be prepared. Grades for ENGR 295, 395, and 495 are based on these reports and the grades will be automatically deferred until the semester following that in which these courses are taken. In order to convert the deferred grade to a Pass/Fail grade, a student must submit a written report on his or her work assignment. *The report is due on the Thursday of the last week of classes of any semester that you are on co-op assignment.* However, if you do two consecutive work assignments without a semester of classes in between, you must submit a report covering the time period corresponding to the first semester, at the end of that semester, and then a second report at the end of the second semester.

Curricula and Summer Courses

Curricula: Sample curricula for earning the 70 credits associated with the junior and senior years are shown on the next page. Students can follow either Curriculum A, for which the first work experience will occur in the summer preceding the junior year, Curriculum B, for which the first work experience will occur in the fall semester of the junior year, or Curriculum C, for which the first work experience will occur in the spring of the junior year. If none of these sample curriculums are applicable for your situation, meet with the Undergraduate Coordinator to develop an individualized curriculum.

Summer session: Students are encouraged to schedule as many summer credits as possible in courses offered by the College of Engineering. A preliminary list of courses that will be offered the next summer, which will serve to satisfy course work required for the major or technical electives, will be made available late in the fall semester. Final listings, for both the College of Engineering and for the other colleges, are published in the *Summer Schedule of Courses* and on the website at: www.lionpath.psu.edu

Academic Credit

If a student completes all three co-op work experiences (ENGR 295, 395, and 495), and only if all three are completed, three academic credits will be granted which may be used to replace one of the four technical selections in the senior year. These three credits will be considered to be in the engineering design category.

CO-OP
ENGINEERING SCIENCE

	Freshman and Sophmore Years	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall (Last Semester)
Curriculum A	Identical to	Work ENGR 295	ESC 312 3 ESC 407H 3 EE 210H 4 ESC 414M 3 AHS 3 **16**	Work ENGR 395	AHS 3 ENGL 202C 3 GHS 3 **9**	Work ENGR 495	ME 302 4 FE 3 FE 3 FE 3 FE 3 **16**	TE 3 TE 3 ESC 410H 3 9	AHS 3 ESC 404H 3 TE 3 TE (ENGR 295,395,495) 3 ESC 411H 3 Tech Lab 1 **16**
Curriculum B	Current	EE 210H 3 ENGL 202C 3 AHS 3 **9**	Work ENGR 295	EMCH 302 4 FE 3 FE 3 FE 3 FE 3 **16**	Work ENGR 395	ESC 407H 3 ESC 312 3 ESC 414M 3 AHS 3 GHS 3 **15**	Work ENGR 495	TE 3 TE 3 ESC 410H 3 9	AHS 3 ESC 404H 3 TE 3 TE (ENGR 295,395,495) 3 ESC 411H 3 Tech Lab 1 **16**
Curriculum C	Programs	ENGL 202C 3 AHS 3 AHS 3 **9**	ESC 312 3 ESC 407H 3 AERSP 308 3 EE 210H 3 ESC 414M 3 **16**	Work ENGR 295	AHS 3 TE 3 GHS 3 **9**	Work ENGR 395	ME 302 4 FE 3 FE 3 FE 3 ESC 410H 3 **16**	Work ENGR 495	ESC 404H 3 TE 3 TE 3 TE (ENGR 295,395,495) 3 ESC 411H 3 Tech Lab 1 **16**

TE = Technical Elective
FE = Foundational Elective

APPENDIX B: Engineering Science and Mechanics Integrated Undergraduate/ Graduate Study

Engineering Science students, because of the flexibility of the curriculum, have a unique opportunity to take advantage of one of two Integrated Undergraduate Graduate (IUG) programs; one administered by the Engineering Science and Mechanics Department and the other administered by the Schreyer Honors College. Application for IUG status may be made in the fourth, fifth, or sixth semester.

IUG status permits students to take on the rigors and research challenges of graduate study at Penn State, coordinating and combining them with their baccalaureate studies. Because some credits earned as an undergraduate may be applied to both degree programs, the time required for completion of integrated undergraduate/graduate studies is normally less than that required to complete separate degree programs. The actual time required is determined by the individual student's objectives and needs. In no case, however, should the acceleration of work in the major be at the expense of the richest possible undergraduate experience; there must be a balance between the accelerated specialization and a sound general education.

The advantages of Integrated Undergraduate/Graduate Status are several: (1) It permits coherent planning of studies through the graduate degree, with advising informed by not only the requirements of the baccalaureate program, but also the longer-range goals of the graduate degree.

For most students, the total time required to reach completion of the higher degree will be shortened. (3) The student will have earlier contact with the rigors of graduate study (in some cases substituting graduate courses for undergraduate requirements) and with graduate faculty; the resources of the Graduate School are accessible to IUG students. (4) While still undergraduates, students with IUG status benefit from their association with graduate students whose level of work and whose intensity of interest and commitment parallel their own.

IUG arrangements have been designed for the truly extraordinary among Scholars: those who have exceptional academic records; whose progress in the major is so advanced that they would be taking graduate courses in later semesters even without IUG status; whose general education progress and plans indicate a readiness to forge ahead with specialization; and who are ready, indeed eager, for that particular challenge of graduate work, advancing knowledge. Schreyer Scholars who believe they are among such students are encouraged to apply for Integrated Undergraduate/Graduate status.

ESM IUG Application Procedures and Guidelines

- IUG proposals may be initiated by Engineering Science students with a GPA of 3.4 or better. Time of admission to the program: Students shall be admitted to an IUG program no earlier than the beginning of the third semester of undergraduate study at Penn State (regardless of transfer or AP credits accumulated prior to enrollment) and no later than the end of the second week of the semester preceding the semester of expected conferral of the undergraduate degree, as specified in the proposed IUG plan of study. It is important to contact the ESM Graduate Officer to start the process.

Example IUG Application Timeline assuming graduation in the 8th semester:

During the 6th semester:

- ✓ Student finds a research adviser and works with the advisor to develop the IUG research plan. The form may be found at: https://sites.esm.psu.edu/wiki/_media/esm_iug_supplemental_application_form.pdf

- ✓ Schedule a meeting with the ESM Graduate Officer to confirm interest in the IUG program and to review the completed IUG supplemental application form.

- ✓ Complete Application to the Graduate School and notify the graduate officer (graduate school does not contact ESM on the status of applications).

- ✓ The ESM graduate admissions committee will review the application and notify the student.

- The application for IUG status consists of the following materials, all of which should be submitted to the ESM Graduate Staff Assistant in the ESM office at 212 EES Building. The complete application will then be forwarded to the ESM Graduate Admissions Committee for review.

  - ✓ A personal statement that summarizes the student's academic progress, outlines long-term goals, states the proposed use of IUG status, and addresses in moderate detail the research area that will constitute the focus of the graduate degree. Usually, one page is sufficient.

  - ✓ An explicit plan of study leading to the graduate degree (form available in the ESM departmental office or online at: http://www.esm.psu.edu/students/iug/) signed by the students' academic adviser. NOTE: As many as 12 of the technical elective credits required for the bachelor' s degree may be applied to both undergraduate and graduate degree programs. A minimum of 50 percent of the courses proposed to count for both degrees must be at the 500 level. Thesis credits may not be double counted.

  - ✓ Three faculty recommendations including one from the academic adviser, as well as the prospective research mentor for the master's program if different. The latter must address the details of the proposed area of research focus and assess the student's ability to conclude the program.

  - ✓ Full transcript (this can be accessed electronically by the ESM office).

  - ✓ A completed Graduate School application form. GRE scores are not required for Penn State undergraduate students.

  - ✓ A financial plan. Both applicant and the prospective research mentor for the master's program must submit a financial plan for funding the applicant for the period between the conferral of the bachelor's and the master's degrees. The financial plan must address the payment of tuition and fees as well as a monthly stipend for living expenses and health insurance, in accordance with the prevailing rules of the Graduate School. Visit http://gradsch.psu.edu/current/funding.html for funding modes and http://tuition.psu.edu/CostEstimate.asp for estimated tuition and fees. The applicant may be self-funded or funded through external scholarships or through a research assistantship by the prospective research mentor. An applicant who is not offered a research assistantship, fellowship, or external scholarship will be eligible for a teaching assistantship from the ESM department, subject to availability of funds. ***When available, TA support for all IUG students is limited to a maximum of 2 semesters.***

- Applicants are notified of the action of the committee. If the application has been approved by the ESM Graduate Admissions Committee, it will then be sent to the Graduate School or Schreyer Honors College, if appropriate, for approval. All Graduate School application fees must be sent along with the application.

- When a candidate has been approved for IUG status by the Engineering Science and Mechanics Department, Schreyer Honors College (if appropriate) and the Graduate School, he or she will receive a letter of notification from the Graduate School Director of Graduate Admissions.

- Undergraduate tuition rates will apply as long as the student is an undergraduate, unless the student receives financial support such as a research or teaching assistantship that covers the payment of graduate tuition.

- A student may retain IUG status for as long as he or she maintains a GPA of 3.2 or better. If the GPA falls below 3.2, the ESM Undergraduate Officer and the ESM Graduate Officer shall jointly review the student's performance to ascertain if the student could be allowed a probationary period of a semester to meet or exceed the 3.20 GPA requirement in light of extenuating circumstances. If IUG status is terminated, the provisions of item 2(b), above, relative to 12 credits being applicable to both an undergraduate and graduate degree program, cease to apply. Termination of the IUG status would require the student to fulfill all regular requirements of the M.S. degree program in order to obtain the M.S. ESMCH degree.

- An appropriate notation of participation in the Integrated Undergraduate/Graduate Study (IUG) program will be made on the student's transcript.

The Schreyer Honors College also offers selected baccalaureate degree candidates the opportunity to integrate undergraduate and graduate courses of study in a continuous program culminating in both a baccalaureate and a master's degree.

A Schreyer Scholar who is granted Integrated Undergraduate-Graduate (IUG) status will have dual enrollment in an undergraduate program and in the Graduate School. Up to 12 graduate credits (400, 500 series) earned as an undergraduate may be applied to both degree programs. Guidelines and information are available from the Schreyer Honors College. It should be noted that while the Schreyer Honors College may only require a single thesis for the Schreyer IUG program, students in the ESM IUG program are required to submit both an undergraduate thesis for the B.S. Engineering Science Degree and a M.S. thesis for the M.S. ESMCH Degree.

When a Schreyer Honors College IUG applicant have been offered admission into the graduate program, all materials will be forwarded to Schreyer Honors College and the applicant should schedule an interview with the program director to discuss her or his IUG proposal.

After this interview, an evaluation of the application is made by the faculty advisory committee of the Schreyer Honors College. The committee will look for (a) an undergraduate record which is superior, even among Schreyer Scholars; (b) evidence of accelerated progress in the major toward graduate study; (c) an indication of how the student compares with other applicants for graduate study and with other Schreyer Scholars in the Department; (d) a plan of study consistent with the requirements and spirit of the program; and (e) strong recommendations that comment incisively on the aforementioned criteria.

Applicants are notified of the action of the committee. If the application has been approved by the Schreyer Honors College, it is sent to the Graduate School for approval. The Graduate School application fee must be sent along with the application.

When a candidate has been approved for IUG status by both the Schreyer Honors College and the Graduate School, he or she will receive a letter of notification from the director of graduate admissions.

At the end of each semester, a student with IUG status must report to the Schreyer Honors College office which courses taken that semester are to be counted both toward the graduate and under- graduate degrees or toward the graduate degree alone. A form for such reporting is available in the Schreyer Honors College office.

Undergraduate tuition rates will apply as long as the student is an undergraduate, unless the student receives financial support, such as an assistantship, requiring the payment of graduate tuition.

A student may retain IUG status for as long as he or she remains in the Schreyer Honors College.
If IUG status is terminated, the provisions of item 2 above, relative to 12 credits being applicable to both an undergraduate and graduate degree program, cease to apply.

An appropriate notation of participation in the Integrated Undergraduate Graduate program will be made on the student's transcript.

APPENDIX C: Minors

1. 1 —Nanotechnology

Nanoscale science and engineering is inherently interdisciplinary and bridges across engineering, materials science, physics, biology, and chemistry. It is a general-purpose, enabling technology. The National Science Foundation (NSF) states that nanotechnology "will affect almost all sectors of society. It will disrupt . . . markets, industrial organizations and business models." The NSF, which is mandated with insuring the nation's future scientific and engineering viability, also says that "50 percent of new products in advanced industrial areas will use nanoscale science and engineering by 2015."

The nanotechnology minor is designed to help prepare students from diverse disciplines for careers in a broad range of industries innovating with nanotechnology. The minor builds on the singular strengths of Penn State's nanofabrication facilities, including its class 1 and class 10 clean rooms, its faculty, and existing academic programs. The minor provides students with fundamental knowledge and skills in simulation, design, modeling, synthesis, characterization, properties, processing, manufacturing, and applications at the nanoscale.

As nanotechnology increasingly bridges across disciplines, a basic understanding of mathematics, physics, biology, and chemistry is recommended. The minor prepares undergraduate students to support major new nanotechnology research programs as graduate students. Interested third- and fourth-year students from related fields in engineering, the chemical, physical, and biological sciences, medicine, life, and agricultural sciences are encouraged to enroll.

Career Opportunities

Nanotechnology is already impacting a broad spectrum of human endeavors, from medicine and catalysis to textiles and quantum computing. The nanotechnology minor prepares students for career opportunities in these exciting fields. Opportunities lie in a variety of industries, including microelectronics, information storage, optoelectronics, photonics, pharmaceuticals, agriculture, and building products. The minor also prepares undergraduate students for multidisciplinary nanotechnology- based advanced degree programs in graduate schools around the world.

Program Requirements Students must:

- Complete at least 18 credits in approved nanotechnology courses
- Take ESC 312 and ESC 313
- Take a minimum of 6 credits at the 400 level
- Achieve a grade of C or better in each course counted toward the 18-credit minimum

Supporting Courses

- CH E 340 Introduction to Biomolecular Engineering
- ESC 419 Electronic Properties and Applications of Materials
- ESC 481 Elements of Nano/Micro-electromechanical System Processing and Design
- ESC 482 Micro-optoelectromechanical Systems (MOEMS) and Nanophotonics
- ESC 483 Simulation and Design of Nanostructures
- ESC 484 Biologically Inspired Nanomaterials

Students may declare a minor via their LionPath account using the UPDATE ACADEMICS tab. All minors must be declared prior to the student applying for graduation. Students may also use the UPDATE ACADEMICS tab to remove a minor from their record.

For more information on the undergraduate Nanotechnology Minor, contact:

Mark Horn, PH D
Department of Engineering Science and Mechanics
The Pennsylvania State University
212 Earth and Engineering Sciences Building
University Park, PA 16802-6812
Tel: 814-865-0332
E-mail: mhorn@engr.psu.edu

1. 2 —Engineering Mechanics

Engineering Mechanics is the engineering science that deals with the effects of loads and environments on particles, or deformable media. It is typically subdivided into statics, or dynamics of rigid bodies and mechanics of deformable bodies.

Statics considers the algebra of vectors, equilibrium, equivalency of force-torque systems, and the concept of the freebody diagram. Special topics include friction, machines, and trusses.

Dynamics treats the motion resulting from unequilibrated force/torque systems through the study of acceleration, velocity, and displacement. An important special topic is simple harmonic motion, caused by a restoring force linearly dependent on displacement—this topic is the foundation of vibrations. Newton's laws and energy principles form the basis of dynamics.

Mechanics of deformable materials covers the internal distribution of force per unit area (stress), local normalized deformation (strain), and material response (strain, strain rate) to stress and temperature. Failure criteria are introduced, as in design. Because the determination of the stress distribution in most engineering components is complex, specialized topics include:

- Strength of Materials: Stretching, bending, twisting of long elastic bodies, Hooke's law, yielding, failure, and design.
- Engineering Materials: Characterization of material properties, deformation mechanisms, and failure criteria.
- Computer Methods/Finite Element Methods
- Experimental Stress Analysis

- Nondestructive Evaluation (NDE)
- Failure Analysis and Prevention
- Composite Materials: Multiple component materials.
- Elasticity: Stress/strain in three-dimensional elastic bodies.
- Viscoelasticity: Stress proportional to strain and strain rate.

The Engineering Science and Mechanics Department offers more than twenty engineering mechanics courses at a level appropriate to an undergraduate minor.

Career Opportunities

Contemporary engineering design of mechanical components requires precise information and modern analysis techniques regarding material response to anticipated loads. Designers must have the analytical and experimental tools to precisely define deformation under load and to characterize dynamic responses as well as prevent mechanical failure. In the event of failure the cause(s) must be ascertained with a view toward redesign and/or material substitution. Thus, high-tech industry has a significant need for those with a sound background in Engineering Mechanics. The aerospace, auto- motive, power, structures, and appliance industries, for example, hire students competent in Engineering Mechanics.
Program Requirements:

Students must:

- Complete at least 18 credits in Penn State Engineering Mechanics courses;
- Take a minimum of 6 credits at the 400-level, and
- Achieve grade of C or better in each EMCH course counted toward 18-credit minimum.
- Students majoring in Engineering Science may apply the three credits of ESC 407H toward the EMCH minor as this course is deemed to cover the EMCH type material of EMCH 407.

Admission Requirements:

Applicants wishing to enroll in the Engineering Mechanics Minor should have completed a back- ground course in mathematics (MATH 250 or 251) and physics (PHYS 211), present an acceptable schedule for completion of requirements, and have a 2.50 grade-point average at the time of application.

Students may declare a minor via their LionPath account using the UPDATE ACADEMICS tab. All minors must be declared prior to the student applying for graduation. Students may also use the UPDATE ACADEMICS tab to remove a minor from their record.

For more information about the undergraduate Engineering Mechanics Minor, contact:

Mark Horn, PH D
Department of Engineering Science and Mechanics
The Pennsylvania State University
212 Earth and Engineering Sciences Building
University Park, PA 16802-6812
Phone: 814-865-0332
Email: mhorn@engr.psu.edu

Appendix D: Concurrent Majors

1. 1– Double Majoring with Engineering Science

When adding a second (or third) major with Engineering Science (ESC), there are numerous courses in one of the two majors that can fulfill course requirements in the other. This appendix lists some typical substitutions that can be used for a number of majors in the College of Engineering.

- Essentially all substitutions outlined in what follows will require a coursepetition;
- To complete two B.S. degrees in engineering disciplines in four years, you should either come in with a number of AP credits or you should be willing to take a number of 18+ credits semesters.

CHEMICAL ENGINEERING & ENGINEERING SCIENCE

The following assume the *General Option* in Chemical Engineering:

- CHEM 112, CHEM 210, and B M B 251 should be used as ESC FoundationalElectives
- CHEM 212 can count as an ESC Technical Elective
- CH E 330 (Process Fluid Mechanics) can substitute for AERSP 308, which is an ESC Foundational Elective
- CH E 220 (Introduction to Chemical Engineering Thermodynamics) and CH E 350 (Process Heat Transfer) can substitute for ME 302
- EE 210H can count for CH E Professional Elective 1
- ESC 414M can count for CH E Professional Elective 2
- EMCH 212H can count for CH E Engineering Elective 1
- ESC 312 can count for CH E Engineering Elective 2
- ESC 404H and ESC 407H can substitute for CH E 360 (Mathematical Modeling in Chemical Engineering)
- CH E 410 (Mass Transfer Operations) can count as ESC Technical Elective 1
- CH E 430 (Chemical Reaction Engineering) can count as ESC Technical Elective 2
- CH E 470 (Design of Chemical Plants) can count as ESC Technical Elective 3
- CH E 480W (Chemical Engineering Laboratory) can count as ESC Technical Elective 4

ELECTRICAL ENGINEERING & ENGINEERING SCIENCE

- CMPSC 201 or ESC 261M should be taken for your programming requirement sinceEE requires C++
- EE 330 (Engineering Electromagnetics) should be interchangeable with ESC 400H, which is an ESC Foundational Elective, subject to approval by the other department
- Two of EE 310 (Electronic Circuit Design I), EE 320 (Introduction to Electro-Optical Engineering), EE 340 (Introduction to Nanoelectronics), EE 350 (Continuous-Time Linear Systems) can count as ESC Foundational Electives

- EE 340 can be substituted for ESC 419 on the CORE list of ESC Foundational Electives. This *only* applies to students double majoring with EE
- ESC 312 can be used as the 3-credit EE Engineering/Science Technical Elective
- As long as a 400-level course is chosen, the 3 credit EE/CMPEN 300/400 level elective will count as ESC Technical Elective 1
- The 6 credits of EE/CMPSEN 400 level elective can count as ESC Technical Electives 2 and 3
- EE 403W (Senior Project Design) can be used as ESC Technical Elective 4
- ESC 414M and ESC 407H can be used to fulfill the 6 required credits of EE Related Electives

ENERGY ENGINEERING & ENGINEERING SCIENCE

- Assuming that your primary college is Engineering, then you do not need to take EM SC 100S
- E M E 301 (Thermodynamics in Energy and Mineral Engineering) can substitute for EMCH 302 (Engineering Thermodynamics)
- E M E 303 (Fluid Mechanics in Energy and Mineral Engineering) can substitute for AERSP 308H (Mechanics of Fluids) as an ESC CORE Foundational Elective
- Two of CHEM 210 (Organic Chemistry I), EGEE 302 (Principles of Energy Engineering), and EGEE 304 (Heat and Mass Transfer) can count as alternative ESC Foundational Electives
- EGEE 411 (Energy Science and Engineering Lab), EGEE 430 (Introduction to Combustion), EGEE 438 (Wind and Hydropower Energy Conversion), and EGEE 441 (Electrochemical Engineering Fundamentals) can count as the four ESC Technical Electives
- PHIL 103 (Introduction to Ethics) will count as one of the required AHS courses
- ESC 414M (Elements of Material Engineering) can substitute for MATSE 201 (Introduction to Materals Science)
- EE 210 (Circuits and Devices) can substitute for EE 211 (Electrical Circuits and Power Distribution)
- ESC 411H (Senior Research and Design Project) can substitute for EGEE 494 (Research Project)
- ESC 400H and ESC 419 can be used to ENENG Technical Electives 1 and 2.

MATHEMATICS (General Option) & ENGINEERING SCIENCE

- CHEM 110 (3), CHEM 111 (1), PHYS 211 (4), PHYS 212 (4), PHYS 214 (2), and
- EDSGN 100 (3) can be used to satisfy the MATH requirement of 17-18 credits *supporting courses*
- EMCH 210H (or either EMCH 211 or EMCH 213), EMCH 212H, EMCH 302, and ESC 414M may be used to satisfy the MATH requirement of 12 credits of *application courses*
- MATH 411 (Ordinary Differential Equations), MATH 412 (Fourier Series and Partial Differential Equations), MATH 417 (Qualitative Theory of Differential Equations), or MATH 421 (Complex Analysis) can count for ESC 404H
- MATH 419 (Theoretical Mechanics) can count as one ESC Technical Elective

- MATH 311 (Concepts of Discrete Mathematics) and MATH 312 (Concepts of Real Analysis) can count as two ESC Foundational Electives
- In addition to ESC requirements and the MATH requirements fulfilled as indicated above, the following 18 credits of MATH courses will need to be taken to obtain the dual degree:
  - ✓ STAT 200 (Elementary Statistics)
  - ✓ MATH 403 (Classical Analysis I)
  - ✓ MATH 414 (Introduction to Probability Theory)
  - ✓ MATH 415 (Introduction to Mathematical Statistics)
  - ✓ MATH 435 (Basic Abstract Algebra) or 436 (Linear Algebra)
  - ✓ One additional 400-level MATH course (***except*** MATH 401, 405, 406, 441, 470 and 471)

MECHANICAL ENGINEERING & ENGINEERING SCIENCE

- For the computer programming requirement, either ESC 261M or CMPSC 200 must be taken since ME requires knowledge of MatLab
- The ME thermodynamics requirement, ME 300 (Engineering Thermodynamics I), should be taken in place of the ESC requirement of EMCH 302. The student will need to use another ME course to make up the 1 credit shortfall
- ME 320 (Fluid Flow), ME 360 (Mechanical Design), and ME 370 (Vibrations of Mechanical Systems) can count for three ESC Foundational Electives since ME 320 substitutes for AERSP 308H, which is on the CORE list of Foundational Electives. Thus, ME 360 and ME 370 would constitute the two courses from the alternative list of Foundational Electives
- The ESC requirement of ESC 414M can be substituted for the ME requirement of MATSE 259 (Properties and Processing of Engineering Materials)
- The ESC requirement of EE 210H can be substituted for the ME requirement of EE 212 (Introduction to Electronic Measuring Systems)
- The two ME requirements, ME 410 (Heat Transfer) and ME 450 (Modeling of Dynamic Systems) can count as two ESC Technical Electives (6 credits)
- ME requires 3 credits of capstone design and 3 credits of ME Technical Electives (METE). Those two courses can count as the other two ESC Technical Electives (6 credits)
- The ESC Foundational Elective, EMCH 416H, should be taken in place of the ME requirement of EMCH 315
- The ESC required MATH 230 should be taken instead of the ME required MATH 231
- ESC 404H and ESC 407H can count for the 6 credits of ME Engineering Technical Electives (ETE)
- ESC 312 can count for the 3 credits of ME General Technical Elective (GTE)

PHYSICS & ENGINEERING SCIENCE

- PHYS 400 (Intermediate Electricity and Magnetism) should be interchangeable with ESC 400H, which is an ESC Foundational Elective, subject to approval by the other department
- PHYS 420 (Thermal Physics) can be substituted for ME 302
    - Two 400-level PHYS courses can be used as ESC Technical Electives
    - One of the two MATH 4xx courses required by PHYS can be substituted for ESC 404H
    - PHYS 402 (Electronics for Scientists) should be interchangeable with EE 210(H), subject to the approval of the other department
    - Either PHYS 410 (Introduction to Quantum Mechanics) or PHYS 412 (Solid State Physics I) can count as a second ESC Foundational Elective (alternative list)

APPENDIX E: Guidelines for Thesis Preparation and Submittal

1. Organization.

Prepare an outline of the thesis and clear it with your supervisor prior to attempting a first draft. Please refer to the recommended thesis contents posted on Canvas and other resources such as J. Schall's book *Style for Students' Effective Writing in Science and Engineering*, Burgess Pub. (1995), pp. 23-28.

2. Format

The regulations will be the same as the Schreyer's Honors College. They can be seen on the web at: http://www.shc.psu.edu/students/thesis/.

The format for the thesis title page is given below.

3. Copies, Paper, Binding

COPIES: it is the responsibility of the student to prepare copies of the thesis and submit them as follows:

- one signed unbound copy due to Dr. Todd for proofing and signature which will be submitted to the department
- SHC Students: on-line thesis submission, plus original signature page to the Schreyer Honors College office along with $20.00 processing fee.
- Non-SHC Students graduating with honors: one additional unbound copy, with original signature page.
- Optional: one signed and unbound copy to his/her Thesis Advisor and Academic Advisor.

PAPER: All paper must be white and alike by shade, weight and rag content. The only exception is the use of photographic paper and computer printouts. Final submission should be printed single-sided and in color.

BINDING: Thesis should be unbound for the department. The copy for the Thesis Advisor and Academic Advisor should be prepared as per the request of each advisor. Thesis title and author are to appear on the front cover.

All costs associated with the presentation (transparencies, etc.) and the printing and reproduction of the theses are the sole responsibility of the student. It may be recalled that there are no textbook costs associated with the six hours of Senior Project 409H, 401H- 411H.

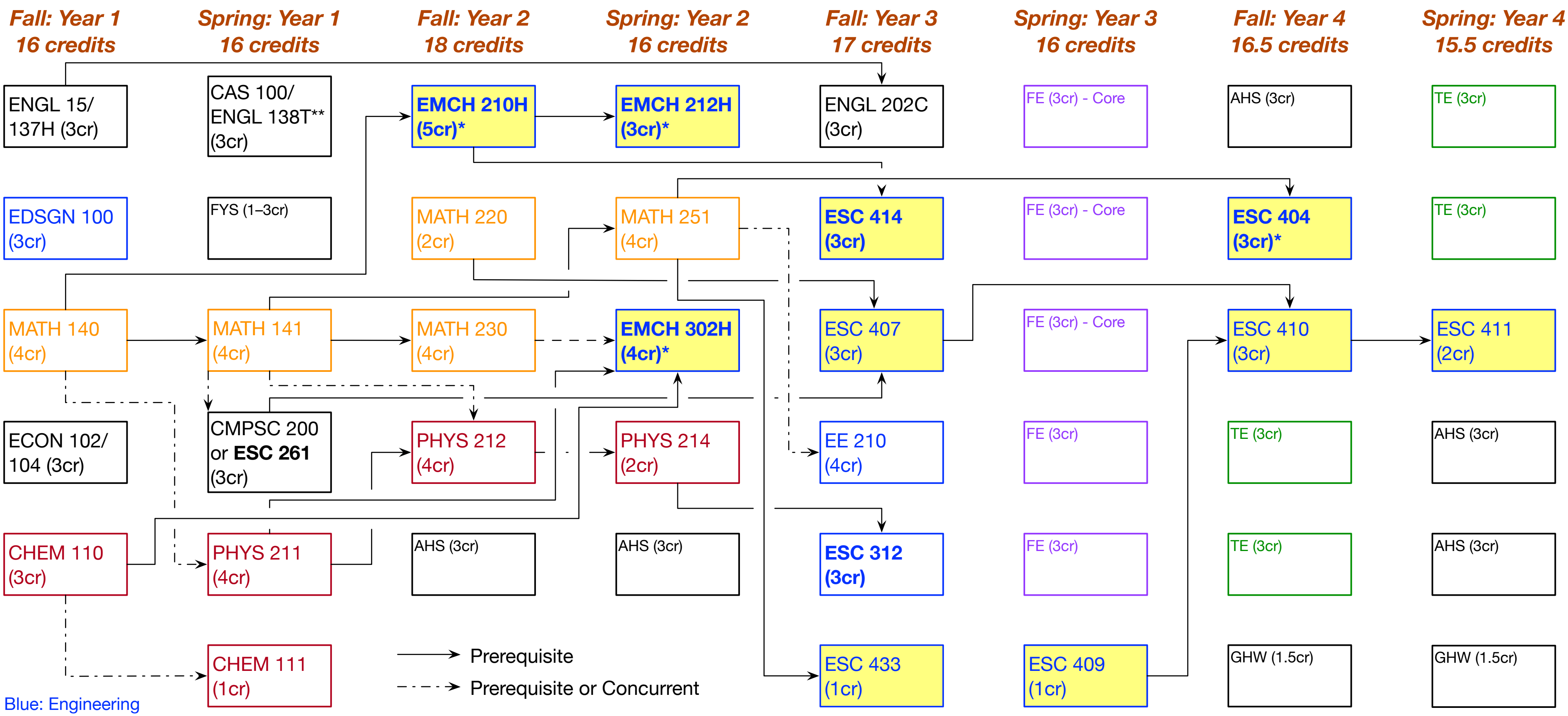
APPENDIX F: Undergraduate Checksheet for Graduation

In preparation for graduation, you should mark off your courses on the course flow chart that is in your advising folder each time you meet with your academic advisor. For the FE (Foundational Electives) and TE (Technical Electives) lists, the course number should be marked on the chart. One the lower right side, list your arts/humanities/social science classes, with showing your U.S. and International Cultures classes.

(This chart is shown again for your convenience on the following two pages)

Engineering Science Flow Chart

Last modified: Aug 23, 2020



Blue: Engineering
Orange: Math
Red: Science
Green: Engr or Sci
Purple: Engr or Sci
Black: Gen Ed/Other

*Indicates that an alternate course is available.

**ENGL 137H is a prereq for ENGL 138T. ENGL 138T also fulfills the FYS requirement.

Boldface indicates the course is only offered that semester.

indicates honors

Foundational Electives (w/ prereqs)

Core FEs (choose 3–5)

- ☐ CHEM 112 (3cr) [Sp,Su,Fa]
  — CHEM 110
- ☐ AERSP 308 (3cr) [Sp]
  — EMCH 212, MATH 251
- ☐ EMCH 416 (3cr) [Sp]
  — EMCH 213 or EMCH 210
- ☐ ESC 400 (3cr) [Sp]
  — EE 210, MATH 250
- ☐ ESC 419 (3cr) [Sp]
  — ESC 312

Alternative FEs (choose 0–2)

Departmental list contains course in AERSP, AE, BMB, BME, BIOL, CE, CHE, CHEM, CMPEN, CMPSC, EE, ESC, EGEE, ENGR, IE, ME, MATH, MATSE, METEO, NUCE; others by petition

General Education (Gen Ed)

Each domain must contain at least one single domain course. Those go in this column.		The 6 credits of integrative studies courses should go in this column.	US Cultures (US)
Arts (GA)			
			Int'l Cultures (IL)
Humanities (GH)			
			Six credits of integrative studies are required via either 6 credits of linked (Z) or 6 credits of interdomain courses (N). Indicate these courses on the left. Applies to students starting or re-enrolling Summer 2018 or later.
Social Sciences (GS)			

Engineering Science: Pre-Med

1st Semester 17 Credits	2nd Semester 16 Credits	3rd Semester 18.5 Credits	4th Semester 18 Credits	5th Semester 18 Credits	6th Semester 19 Credits	7th Semester 19 Credits	8th Semester 15.5 Credits
CHEM 110*# [3 Credits]	CAS 100 A/B* or ENGL 138T** [3 Credits]	EMCH 210H*^ [5 Credits]	BIOL 141 [3 Credits]	BMB 251 [3 Credits]	BMB 401 [3 Credits]	EE 210* ** [4 Credits]	ECON 102 or 104 [3 Credits]
CHEM 111 [1 Credit]	CHEM 112* [3 Credits]	BIOL 110 [4 Credits]	BIOL 142 [1 Credit]	CHEM 212 [3 Credits]	ESC 261M~ or CMPSC 200~ [3 Credits]	ENGL 202C* (ENGL 015 is Prerequisite) [3 Credits]	ESC 411^^ [2 Credits]
EDSGN 100 [3 Credits]	CHEM 113 [1 Credit]	MATH 230 [4 Credits]	CHEM 210 [3 Credits]	CHEM 213 [2 Credits]	ESC 409^^ [1 Credit]	ESC 404*^^ [3 Credits]	TECHNICAL ELECTIVE [3 Credits]
ENGL 015* or ENGL 030* or ESL 015* or ENGL 137H*> [3 Credits]	FYS [1 Credit]	PHYS 212*# [4 Credits]	EMCH 212H*^ [3 Credits]	ESC 312 [3 Credits]	FOUNDATIONAL ELECTIVE (Core) (SEE BELOW) [3 Credits]	ESC 407*^^ [3 Credits]	HIST 124 MAJOR SPECIFIC GEN ED [3 Credits]
MATH 140*# MATH 140E [4 Credits]	MATH 141*# MATH 141E [4 Credits]	GHW [1.5 Credits]	MATH 251*# [4 Credits]	ESC 414*^^ [3 Credits]	FOUNDATIONAL ELECTIVE (Core) (SEE BELOW) [3 Credits]	ESC 410^^ [3 Credits]	GEN ED GA; IL or US [3 Credits]
PSYCH 100 MAJOR SPECIFIC GEN ED [3 Credits]	PHYS 211*# [4 Credits]		EMCH 302H* [4 Credits]	MATH 220~ [2 Credits]	PHIL 132 MAJOR SPECIFIC GEN ED [3 Credits]	TECHNICAL ELECTIVE [3 Credits]	GHW [1.5 Credits]
				PHYS 214~ [2 Credits]	SOC 001 MAJOR SPECIFIC GEN ED [3 Credits]		

* Course requires a grade of C or better for the major
\# Course is an Entrance to Major requirement
** Course is frequently honors optioned
>< ENGL 137H is a prerequisite for ENGL 138T
^ An alternate course is available the other semester
^^ Honors course
——→ = Prerequisite
- - - -→ = Prerequisite or Concurrent

Spring Only Courses

Fall Only Courses

Foundational Electives (FE)
with prerequisites

Core (Select 3-5 Courses)
- ☑ CHEM 112 (3cr) — *CHEM 110*
- ❑ AERSP 308H (3cr) [SP] — *EMCH 212, MATH 251*
- ❑ ESC 400H (3cr) [SP] — *EE 210, MATH 250*
- ❑ EMCH 416H (3cr) [SP] — *EMCH 213 or 210*
- ❑ ESC 419 (3cr) [SP] — *ESC 312*

Alternative FEs
- BIOL 141
- CHEM 210

Updated: 6/6/19
advising.engr.psu.edu

This is meant to support the current Suggested Academic Plan found at bulletins.psu.edu

E SC Foundational Electives

The intent of the Foundational Elective (FE) courses is to provide some flexibility in the junior year while maintaining a high level of technical content (i.e., not intro/overview courses), providing breadth of topics covered, and supporting potential deeper study in the senior year.

A total of five FE courses are required. Some courses on these lists are suitable as Technical Electives, but each course can be used to fill one degree requirement. No more than one 100-level course may be used.

Core (select 3–5 courses)

- CHEM 112 (Chemical Principles II)
- AERSP 308H (Mechanics of Fluids)
- E MCH 416H (Failure and Failure Analysis of Solids)
- E SC 400H (Electromagnetic Fields)
- E SC 419 (Electronic Properties and Applications of Materials)

The following are acceptable core subtitutions:

- AERSP 308H ➔ AERSP 311, BME 409, CH E 330H, C E 360, EME 303, or M E 320
- E SC 419 ➔ E SC 314
- E SC 400H ➔ E E 330 or PHYS 400

Alternative (select 0–2 courses)

- AERSP 301 (Aerospace Structures)
- AERSP 304 (Dynamics & Control of Aerospace Systems)
- AERSP 309 (Astronautics)
- AERSP 312 (Aerodynamics II)
- A E 311 (Fundamentals of Electrical and illumination Systems for Building)
- B E 300 (Biological Systems)
- B E 302 (Transport Processes for B E)
- B E 304 (Engineering Properties of Food and Biological Materials)
- B E 306 (Machines for Agricultural & Biological Processing)
- B M B 251 (Molecular and Cell Biology I)
- BME 201 (Cell and Molecular Bioengineering)
- BME 301 (Analysis of Physiological Systems)
- BME 303 (Bio-continuum Mechanics)
- BIOL 110 (Biology: Basic Concepts and Biodiversity)
- BIOL 141 (Introductory Physiology)
- BIOL 230M (Molecules and Cells)
- BIOL 240M (Function and Development of Organisms)
- C E 340 (Structural Analysis)
- C E 335 (Engineering Mechanics of Soils)
- C E 370 (Introductions to Environmental Engineering)
- CH E 210H (Introduction to Material Balances)
- CH E 320H (Phase and Chemical Equilibria)
- CHEM 210 (Organic Chemistry)
- CMPEN 270 (Digital Design: Theory and Practice)
- CMPEN 331 (Computer Organization and Design)
- CMPSC 122 (Intermediate Programming)
- CMPSC 221 (Object Oriented Programming with Web-Based Applications)
- CMPSC 311 (Introduction to Systems Programming)
- CMPSC 312 (Computer Organization and Architecture)
- CMPSC 360 (Discrete Mathematics for Computer Science)
- E E 310 (Electronic Circuit Design 1)
- E E 320 (Introduction to Electro-Optical Engineering)
- E E 340 Introduction to Nanoelectronics)
- E E 350 (Continuous-Time Linear Systems)
- E SC 313 (Intro to Principles, Fabrication Methods, and Appl. of Nanotechnology)
- E SC 3xx (Physical Principles of Living Organisms)
- E SC 4xx (Multidisciplinary Design Project)
- EGEE 302 (Principals of Energy Engineering)
- EGEE 304 Heat and mass Transfer)
- ENGR 320 (Materials Properties Measurement I)
- I E 305 (Product Design, Specification & Measurement)
- I E 311 (Principles of Solidification Processing)
- I E 312 (Product Design and Manufacturing Processes)
- I E 322H (Probabilistic Models in I E)
- I E 323 (Statistical Methods in I E)
- I E 327 (Introduction to Work Design)
- I E 330 (Information Technology for I E)
- M E 360 (Mechanical Design)
- M E 367 (Machine Design)
- M E 370 (Vibration of Mechanical Systems)
- M E 380 (Machine Dynamics)
- MATH 311M (Concepts of Discrete Mathematics)
- MATH 315 (Foundations of Mathematics)
- MATSE 400 (Crystal Chemistry)
- MATSE 402 (Materials Process Kinetics)
- MATSE 443 (Introduction to the Materials Science of Polymers)
- METEO 300 (Fundamentals of Atmospheric Science)
- NUCE 301 (Fundamentals of Reactor Physics)
- NUCE 309 (Analytical Techniques for Nuclear Concept)

APPENDIX G:
PORTFOLIO CONTENTS ENGINEERING SCIENCE

The Engineering Science curriculum is designed so that when you graduate with a B.S. degree in Engineering Science, we expect you to have developed the outcomes in the following table (ABET, Accreditation Board for Engineering and Technology, calls these "outcomes"):

ABET	Outcome Description
	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.

Transcripts alone do not demonstrate that you have met all of these outcomes, whereas your portfolio gives you a chance to show how you have met, or exceeded, these expectations.

The purpose of this document is to help you assemble your portfolio during your time at Penn State so that you can show that you have achieved these seven outcomes.

Some Examples of the Essential Elements

Complex Problems: Evidence of your ability to formulate and solve complex engineering problems can come from many sources including but not limited to:

- senior thesis project
- ESC 407H
- ESC 404H
- EMCH 302H
- foundational electives
- technical electives
- Co-op or internships
- club projects

Ability to Design: Evidence can come from many sources including, but not limited to, the following courses and experiences:

- EDSGN 100
- design of circuits and devices in EE 210H
- the design project in ESC 416H
- algorithm design in ESC 407H
- the multidisciplinary design project in ESC 460M
- design of a process, algorithm, and/or device in your technical electives
- design of experiments, algorithms, software, processes, products, and/or de vices in ESC 410H/411H
- design done as part of internships or co-ops
- extracurricular design (e.g., Rube Goldberg competition, PSU Robotics Club, PSU Society of Automotive Engineers, etc.)

This evidence can be included as, for example, photos, a report or paper, and/or video saved on an optical disc.

Communication: Communication skills should be developed over the course of your academic career in the writing of reports, and the delivery of oral presentations to various audiences with both technical and non-technical backgrounds. Some places to find examples might include:

- literature reviews
- thesis document
- thesis defense
- CAS 100 presentations
- ENGL 202C writing assignments
- course related design reports
- non-technical and technical abstracts
- poster presentations related to your research
- teaching/classroom support activities
- lab group presentations

Professional & Ethical Responsibility: Include evidence of skills and experiences acquired through courses, internships, co-ops, workshops, or plant trips. If you are working on the leadership development minor, you should have additional examples.

Some other things to look for:

- *Global/Environmental Impact:* If you have completed assignments on or worked in the areas of sustainable energy, resources for underdeveloped communities, recycling, etc. you should have several pieces of evidence in this area.

- *Professional Ethics:* Observations of coworkers or supervisors facing ethical dilemmas, classmates violating academic integrity, or standing up others who have behaved unethically.

- *A Knowledge of Contemporary Issues:* Highlight international travel and insights gained about the global community. This can include assignments from courses that cover diversity and multicultural issues (most courses satisfying the International Cultures requirement could likely be included).

Teamwork: Describe courses and activities where you worked in teams, including as part of your senior research and design project. The reflection for this section should demonstrate an understanding of diverse teams consisting of multiple disciplines and multiple degrees of experience as well as the leadership roles you have served in, and the ways in which your groups delegated responsibilities (i.e., not just students). Sample group reports should be included.

Experimentation & Interpretation: The ability to develop and conduct experiments as well as analyzing the results and interpreting the data is critical for engineers. Examples of this should be available through the curriculum with some examples provided from:

- senior thesis
- foundational electives
- technical electives
- EE 210
- club projects
- summer research experiences
- internships and co-op experiences

Learning Strategies: Include evidence expressing your interest in continuing your education, either part-time while employed in industry or full-time. This can include becoming a member of a professional society. This section can also include things like learning to play an instrumental, or developing new skills. Show us how you have learned to use new areas of your mind throughout your academic career, including areas outside of your formal education.

Additional Things to Include

While the above suggestions demonstrate ability for the five *essential* targeted outcomes, your portfolio may also become a personal showcase for additional aspects of your educational growth and development. For example, you might also consider including:

Service: Service activities, including those external to Penn State, should be included.

Teaching Experience: Include evidence from formal programs such as the Teaching Intern program or the Women in Engineering Program Girl Scout presentation, as well as less formal teaching through things like tutoring high school students.

Academic Excellence: Examples of honors, awards, accomplishment in courses, recognition in professional circles, military, or groups external to PSU, Dean's list recognition.

Some General Suggestions

√ The front of the portfolio should contain an index of materials, which we encourage you to start early rather than at the end of four years.

√ *After your portfolio is essentially complete*, the first page(s) of the portfolio should be a summary statement assessing how the entire body of the portfolio demonstrates accomplishments with regard to the Engineering Science program outcomes described at the beginning of this document. This statement should also include an overall reflection on your personal and professional development during your time at Penn State.

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