

Engineering Science

Undergraduate Program Guide 2008-2009



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Foreward

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 master's and doctoral degrees since 1940.

The baccalaureate major in Engineering Science was established in 1952 to provide an enriched interdisciplinary 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.

This year we are excited to announce that Engineering Science has 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 I: E SC Curriculum Description

I. 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.

I. 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.

I. 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.

I. 4 —Program Outcomes

At the time of graduation, Engineering Science graduates are expected to attain:

- A. an ability to apply knowledge of mathematics, science, and engineering
- B. an ability to design and conduct experiments, as well as to analyze and interpret data

C. an ability to design a system, component, or process to meet desired needs with realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

D. an ability to function on multi-disciplinary teams

E. an ability to identify, formulate, and solve engineering problems

F. an understanding of professional and ethical responsibility

G. an ability to communicate effectively

H. the broad education necessary to understand the impact of engineering solutions in a global, economical, environmental, and social context

I. a recognition of the need for, and an ability to engage in life-long learning

J. a knowledge of contemporary issues

K. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

I. 5 —Program Educational Objectives

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

1. Participate in lifelong learning activities including but not limited to masters, doctorate, medical, and law degrees, continuing education, leadership development, management training, 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.
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, by filing patents, in technical publications (journals, reports, memoranda), and to the general public.
5. Use state-of-the-art tools for the benefit of society.
6. Participate in and promote the value of diversity in society.
7. Encourage and foster future generations of engineers through mentoring, service, and outreach.

I. 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 following flowchart shows the typical semester-by-semester placement of courses at University Park Campus. At a Commonwealth Campus, the differences are (1) that E MCH 211 plus E MCH 213 (6 credits) will replace E MCH 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 two senior project courses, E SC 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)

E MCH 197: Special Topics (1 - 9):

E MCH 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

E MCH 210H: Equilibrium Mechanics, Honors (5). Equilibrium of particles and rigid bodies; stresses, strains, and displacements in elastic; rods, torsion bars, beams, trusses, frames, and columns. Prerequisite: or concurrent: MATH 141 [alternate course: E MCH 210 or E MCH 211 and E MCH 213]

E MCH 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

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

E MCH 212H: Mechanics of Motion, Honors (3). Kinematics of a particle; relative motion; kinetics of a mass-point; kinetics of a rigid body; work-energy; impulse-momentum. Prerequisite: E MCH 211, E MCH 210H, or E MCH 210; MATH 141 [alternate course: E MCH 212]

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

E MCH 296: Independent Studies (1 -18 per semester) :

E MCH 297: Special Topics (1 - 9):

E MCH 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: E MCH 213 , E MCH 210H , or E MCH 210

E MCH 397: Special Topics (1 - 9) :

E MCH 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: E MCH 213, E MCH 210H, or E MCH 210

E MCH 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: E MCH 213, E MCH 210H, or E MCH 210

E MCH 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: E MCH 315, E MCH 316 [may not be taken for credit by students who received credit for E MCH 416H]

E MCH 407: Computer Methods in Engineering Design (3). Numerical methods and computer programming, with applications to design problems in structural mechanics, dynamics, vibrations, and stability. Students who have passed E SC 407H may not schedule this course. Prerequisite: CMPSC 201C, CMPSC 201F, or E SC 261M; E MCH 213, E MCH 210H, or E MCH 210

E MCH 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: E MCH 212 or E MCH 212H; MATH 230

E MCH 412: Experimental Methods in Vibrations (3). Systems of one or more degrees of freedom, mechanical vibrations, vibration properties of materials, vibration techniques in nondestructive testing. Prerequisite: E MCH 454

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

E MCH 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: E MCH 213, E MCH 210H, OR E MCH 210

E MCH 454 (M E): 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: E MCH 212 or E MCH 212H; M E 054 or E SC 407H

E MCH 461 (M E): Applied Finite Element Analysis (3). Computer modeling and fundamental analysis of solid, fluid, and heat flow problems using existing computer codes. Prerequisite: CMPSC 201C, CMPSC 201F, or E SC 261M; E MCH 213, E MCH 210H, or E MCH 210

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

E MCH 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: E MCH 471

E MCH 496: Independent Studies (1 -18) :

E MCH 497: Special Topics (1 - 9):

E SC 261M: Computational Methods in Engineering, Honors (3). Modeling, solving engineering problems using FORTRAN, software libraries, graphics. Reports on root search, curve fitting, finite differences, algebraic equations. Prerequisite: or concurrent: MATH 141 [alternate course: CMPSC 201]

E SC 197: Special Topics (1 - 9):

E SC 296: Independent Studies (1 -18):

E SC 297: Special Topics (1 - 9):

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

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

E SC 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. Prerequisite: PHYS 212

E SC 397: Special Topics (1 - 9):

E SC 400H: 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: E E 210, MATH 250

E SC 404H: 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

E SC 405H: Engineering Applications of Field Theory, Honors (3) : Field concepts in engineering, derivation of field equations, mathematical solutions, applications stressing universality of approaches to all fields of engineering. Prerequisite: MATH 250

E SC 407H: Computer Methods in Engineering Science, Honors (3).

Application of numerical methods to problems in engineering science. Algebraic and differential equations; integration; interpolation; eigenvalue problems; linear programming. Students who have passed E MCH 407 may not schedule this course for credit. Prerequisite: CMPSC 201C, CMPSC 201F, or E SC 261M. Prerequisite or concurrent: E MCH 212 or E MCH 212H

E SC 410H: 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 407H

E SC 411H: 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 410H

E SC 414M: Elements of Material Engineering, Honors (3). Structure and imperfections in engineered materials; their influence on properties, behavior, and processing. Applications of metals, ceramics, polymers, and composites. Prerequisite: E MCH 213, E MCH 210H, or E MCH 210; PHYS 237

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

E SC 433H: Engineering Science Research Laboratory Experience, Honors (1). Student "hands-on" experiences spanning ESM Research laboratories: environmental degradation, fatigue, MEMS, neural networking, smart materials, ultrasonics, etc. Prerequisite: E E 203, E SC 414M

E SC 445: Semiconductor Optoelectronic Devices (3). The course will present the basic engineering science and technology involved in modern semiconductor optoelectronic devices. Prerequisite: E E 340, E E 368, or E SC 314

E SC 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: CHEM 112, MATSE 400, MATSE 401, MATSE 402

E SC 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: E SC 414M or MATSE 259; MATSE 420 or MATSE 421

E SC 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: E MCH 315, E SC 414, OR MATSE 259

E SC 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: E MCH 213, or E MCH 315, or E SC 312

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

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

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

E SC 496: Independent Studies (1 -18) :

E SC 497: Special Topics (1 - 9):

I. 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: E MCH 212 or E MCH 212H; MATH 251

BIOL 141 (GN) Introductory Pgyaiology (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.

BIOE 201 Analysis of Molecules and Cells (3). An analytical study of molecular and cellular phenomena including functional and metabolic interactions. Prerequisite: BIOL 141 , CHEM 112, MATH 141 , PHYS 212

BIOE 303 Bio-Continuum Mechanics (3). Mechanical properties of fluids and solids with applications to tissue mechanics and vascular system. Prerequisite: BIOL 141 , E MCH 210 , MATH 251

BIOE 401 Introduction to Bioengineering (3). Application of fluid mechanics, mass transfer, electrical theory, and control theory to physiological systems and internal artificial organs. Prerequisite: MATH 250 , PHYS 212 . Prerequisite or concurrent: BIOL 141 or BIOL 472

B M B 251 (MICRB) Molecular and Cell Biology I (3). Biomolecules, genetic mechanisms, organization of cells and their organelles, DNA replication, protein synthesis, membranes, the cell nucleus, energy conversion. Prerequisite: CHEM 112

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 012 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.

E E 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 eigenvectors; 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

M E 302 Engineering Thermodynamics (4). Engineering thermodynamics and heat transfer, with pertinent applications to devices important in mechanical engineering. For students in engineering science. Prerequisite: CHEM 112, PHYS 211, and MATH 230 or MATH 231

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, PHYS 211. Concurrent: MATH 141

I. 10 —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 1 on the next page provides the list of Technical Electives and a breakdown of the Engineering Science and Engineering Design content.

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.

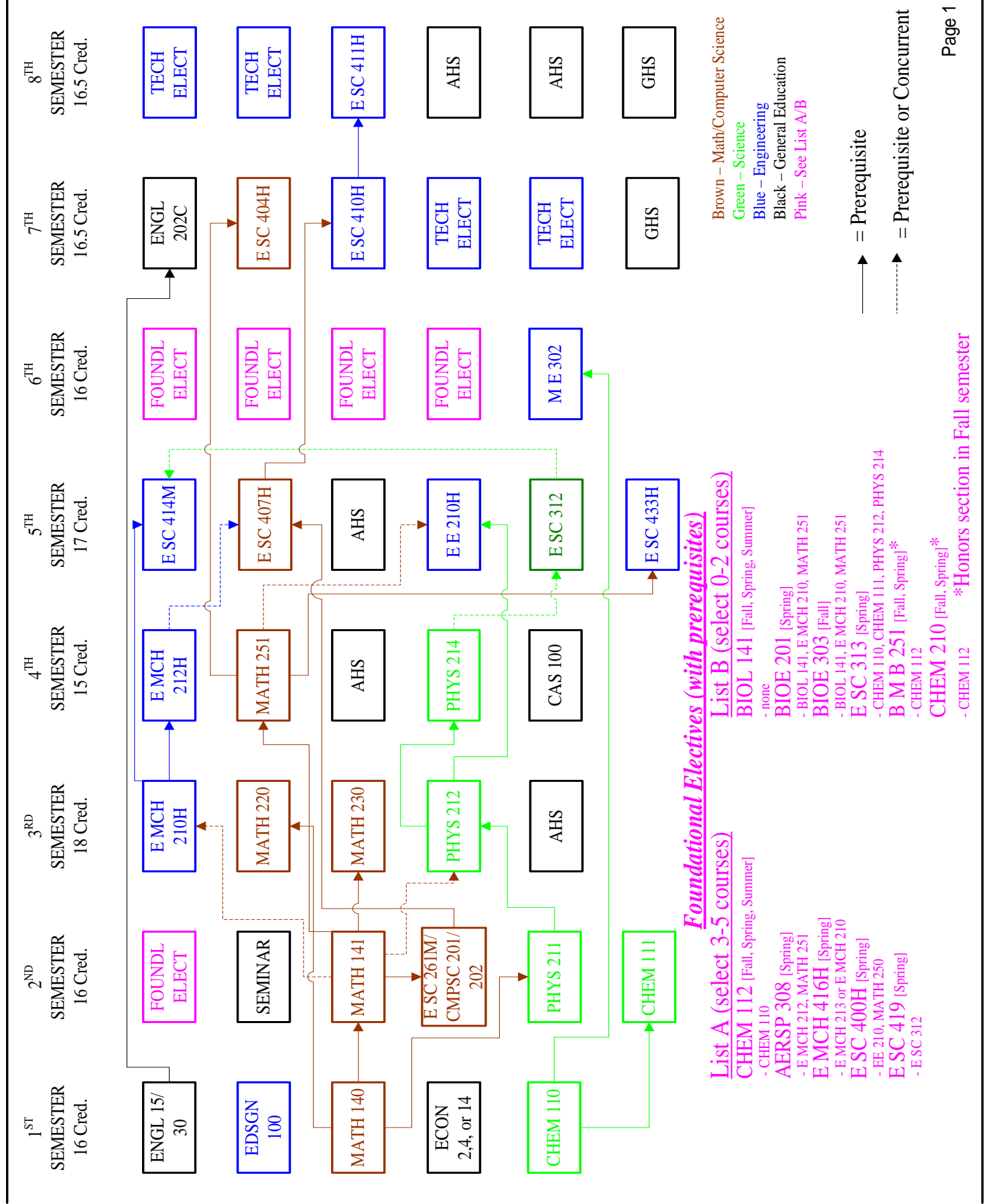
Technical Elective Course list

Course	#	Engineering		Course	#	Engineering		Course	#	Engineering		Course	#	Engineering		Course	#	Engineering	
		Science	Design			Science	Design			Science	Design			Science	Design			Science	Design
ACS	402	3.0		AE	467		3.0	CSE	428	2.0	1.0	EMCH	400	2.0	1.0	IE	462	1.2	1.8
ACS	403	1.0	2.0	AE	470		3.0	CSE	430W	1.0	1.0	EMCH	402	2.0	1.0	IE	463	1.5	1.5
AERSP	401A		3.0	AE	471		3.0	CSE	431	2.0	1.0	EMCH	403	1.0	2.0	IE	464	*	*
AERSP	401B		3.0	AE	472		3.0	CSE	441W	1.0	1.0	EMCH	408	2.0	1.0	IE	466	*	*
AERSP	402A		2.0	AE	473		3.0	CSE	447	2.0	1.0	EMCH	409	3.0		IE	467	*	*
AERSP	402B		2.0	AE	474		3.0	CSE	451	2.0	1.0	EMCH	412	1.0	2.0	IE	468	*	*
AERSP	404H	1.0	2.0	AE	475		3.0	CSE	455	3.0		EMCH	416H	1.0	2.0	MATSE	4xx	*	*
AERSP	407	2.0	1.0	AE	476		3.0	CSE	456	3.0		EMCH	440	2.0	1.0	ME	403	1.0	2.0
AERSP	410	2.0	1.0	AE	477		3.0	CSE	457	2.0	1.0	EMCH	446	3.0		ME	405	2.0	1.0
AERSP	411	2.0	1.0	BIOE	401	1.0		CSE	458	2.0	1.0	EMCH	454	*	*	ME	407	3.0	
AERSP	412	3.0		BIOE	402	2.0	1.0	CSE	460	3.0		EMCH	461	2.0	1.0	ME	408	2.0	1.0
AERSP	413	2.0	1.0	BIOE	403		1.0	CSE	465	3.0		EMCH	471	2.0	1.0	ME	409	1.0	2.0
AERSP	420	2.0	1.0	BIOE	406	*	*	CSE	467	3.0		EMCH	473	1.0	2.0	ME	411		3.0
AERSP	423	3.0		BIOE	413	*	*	CSE	468	3.0		ENGR	407	1.0	2.0	ME	412	2.5	0.5
AERSP	424	2.0	1.0	BIOE	419	1.0	2.0	CSE	471	2.0	1.0	ENGR	408	-	-	ME	413	2.0	1.0
AERSP	425	2.0	1.0	BIOE	423	*	*	CSE	472	1.0	2.0	ENGR	409	1.0		ME	414W		4.0
AERSP	430	2.0	1.0	BIOE	433	*	*	CSE	473	1.0	2.0	ESC	400H	2.5	0.5	ME	415W		4.0
AERSP	440	2.0	1.0	CH E	480W	1.0	2.0	CSE	477	1.0	2.0	ESC	405H	3.0		ME	416	2.0	1.0
AERSP	450	2.0	1.0	CH E	410	2.0	1.0	CSE	478	1.0	2.0	ESC	406H	3.0		ME	418	2.0	1.0
AERSP	460	2.0	1.0	CH E	430	2.0	1.0	CSE	481	2.0	1.0	ESC	419	2.5	0.5	ME	420	1.0	2.0
AERSP	473	1.0	2.0	CH E	415	1.5	1.5	CSE	485	2.0	1.0	ESC	445	2.0	1.0	ME	421	3.0	
AERSP	490	3.0		CH E	432	1.0	1.0	CSE	486	2.0	1.0	ESC	450	2.0	1.0	ME	434	2.0	1.0
ABE	400	2.0		CH E	435	1.0	1.0	EE	402W		3.0	ESC	455	1.0	2.0	ME	440	2.0	1.0
ABE	401	2.0		CH E	438	1.5	1.5	EE	403W		3.0	ESC	456	1.0	2.0	ME	450	1.0	2.0
ABE	402	2.0	1.0	CH E	441	1.5	1.5	EE	411	3.0	0.0	ESC	475	2.0	1.0	ME	451	1.0	2.0
ABE	403	1.0	1.0	CH E	446	3.0		EE	412	2.0	1.0	ESC	481	1.5	1.5	ME	452	1.0	2.0
ABE	404	3.0		CH E	448	1.5	1.5	EE	414	2.0	1.0	ESC	482	2.0	1.0	ME	454	2.0	1.0
ABE	405	2.0	1.0	CH E	450	1.5	1.5	EE	418	1.0	2.0	ESC	483	1.5	1.5	ME	455	1.0	2.0
ABE	406	1.0	1.0	CH E	453	1.5	1.5	EE	419	2.5	0.5	ESC	484	1.5	1.5	ME	456	1.0	2.0
ABE	407	1.0	1.0	CH E	455	1.5	1.5	EE	420	2.0	1.0	IE	400	*	*	ME	458	1.0	2.0
ABE	408	1.0		CH E	465		3.0	EE	422	1.0	2.0	IE	402		3.0	ME	460	1.0	2.0
ABE	461		3.0	C E	410W		3.0	EE	423	2.0	1.0	IE	404	*	*	ME	461	2.0	1.0
ABE	462		3.0	C E	421W		3.0	EE	425	x	x	IE	405	3.0		ME	462	1.0	2.0
ABE	465		3.0	C E	422	1.5	1.5	EE	428	2.0	1.0	IE	408W	3.0		ME	466H		3.0
ABE	467		3.0	C E	423	1.0	2.0	EE	429	2.0	1.0	IE	414	*	*	ME	470	2.0	1.0
ABE	468	1.0	2.0	C E	424		3.0	EE	432	2.0	1.0	IE	418	1.0	2.0	ME	476	2.0	1.0
ABE	469W	1.0	2.0	C E	432		3.0	EE	433	2.0	1.0	IE	419		3.0	NUC E	401	1.0	2.0
ABE	477	2.0	1.0	C E	435	1.0	2.0	EE	438	1.0	2.0	IE	423	1.0	2.0	NUC E	403	2.0	1.0
AE	401	1.0	2.0	C E	436	-	-	EE	439	2.0	1.0	IE	424	3.0		NUC E	405	3.0	
AE	402	1.5	1.5	C E	438W		3.0	EE	447	1.0	2.0	IE	425	3.0		NUC E	408		3.0
AE	403		3.0	C E	447	3.0		EE	448	1.0	2.0	IE	426	1.0	2.0	NUC E	409	3.0	
AE	430	3.0		C E	448W		3.0	EE	453	2.0	1.0	IE	428	*	*	NUC E	420	3.0	
AE	431		3.0	C E	462	1.5	1.5	EE	456	2.0	1.0	IE	430	1.0	2.0	NUC E	428	3.0	
AE	439	3.0		C E	465W		3.0	EE	458	2.0	1.0	IE	435	*	*	NUC E	430		3.0
AE	444		3.0	C E	472W		3.0	EE	459	3.0		IE	438		3.0	NUC E	431W		4.0
AE	454		3.0	C E	475	3.0		EE	461	2.0	1.0	IE	450	1.0	2.0	NUC E	444	1.0	
AE	455	1.0	2.0	C E	476	1.0	2.0	EE	478	1.0	2.0	IE	451	1.0	2.0	NUC E	445		3.0
AE	456	2.5	0.5	C E	479	3.0		EE	485	2.0	1.0	IE	452	*	*	NUC E	450	3.0	
AE	458	1.0	2.0	CSE	411	2.0	1.0	EE	486	2.0	1.0	IE	453	1.0	2.0	NUC E	451	3.0	
AE	461		3.0	CSE	418	1.0	2.0	EE	490	3.0		IE	454	3.0		NUC E	460	2.0	1.0
AE	464		3.0	CSE	420W	1.0	1.0	EE	492	2.0	1.0	IE	455	3.0		NUC E	470	2.0	1.0
AE	466		3.0	CSE	421	2.0	1.0	EGEE	410	1.0	2.0	IE	456		3.0	NUC E	490	3.0	

* Breakdown to be determined

† If used as a Foundational Elective, this course will not count as a Technical Elective

ENGINEERING SCIENCE



List A (select 3-5 courses)

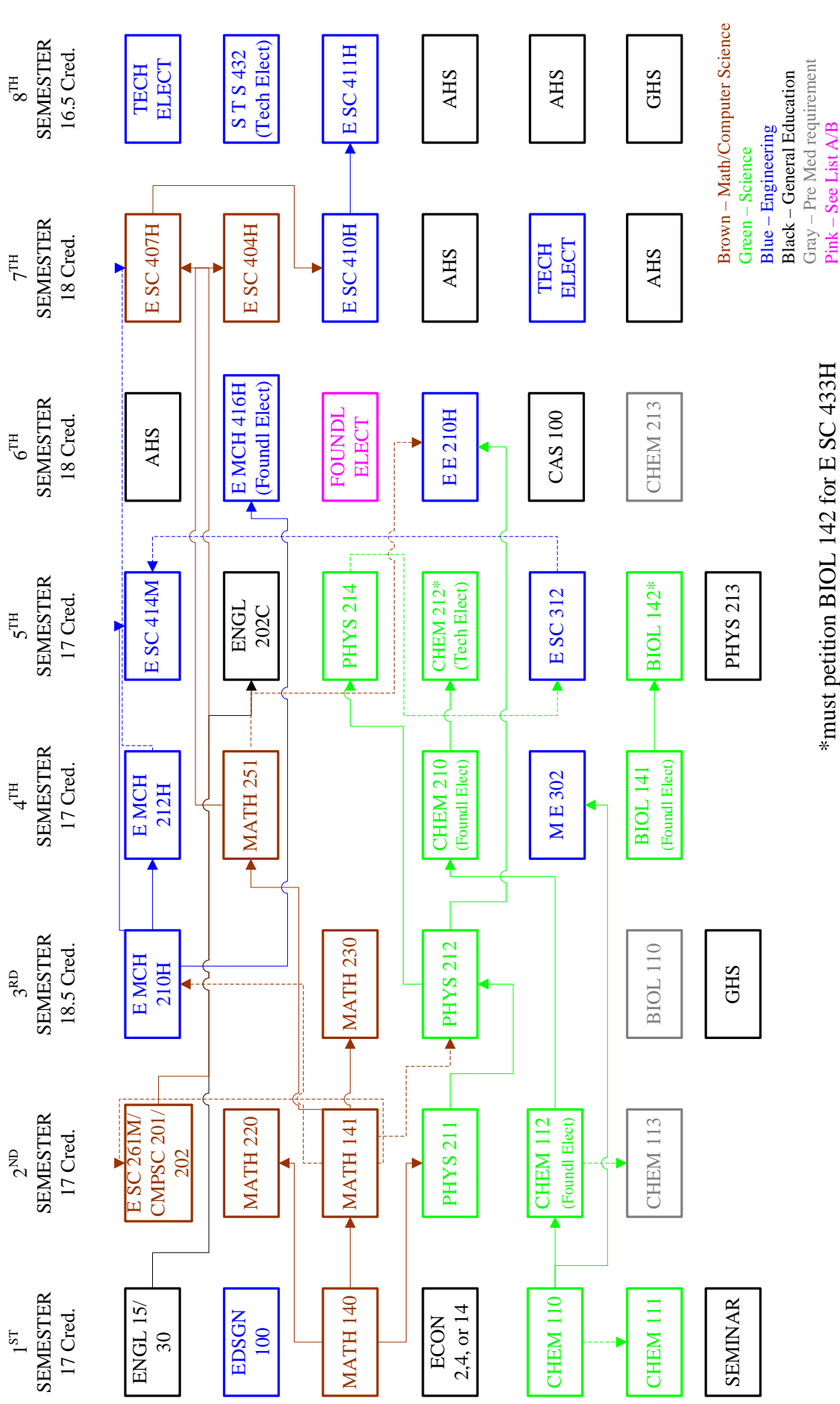
- CHEM 112 [Fall, Spring, Summer]
- CHEM 110
- AERSP 308 [Spring]
- E MCH 212, MATH 251
- EMCH 416H [Spring]
- E MCH 213 or E MCH 210
- E SC 400H [Spring]
- EE 210, MATH 250
- E SC 419 [Spring]
- E SC 312

Foundational Electives (with prerequisites)

List B (select 0-2 courses)

- BIOL 141 [Fall, Spring, Summer]
- none
- BIOE 201 [Spring]
- BIOL 141, E MCH 210, MATH 251
- BIOE 303 [Fall]
- BIOL 141, E MCH 210, MATH 251
- E SC 313 [Spring]
- CHEM 110, CHEM 111, PHYS 212, PHYS 214
- B M B 251 [Fall, Spring]*
- CHEM 112
- CHEM 210 [Fall, Spring]*
- CHEM 112

ENGINEERING SCIENCE – Pre-Med Plan – 138 Credits



Brown – Math/Computer Science
 Green – Science
 Blue – Engineering
 Black – General Education
 Gray – Pre Med requirement
 Pink – See List A/B

*must petition BIOL 142 for E SC 433H and CHEM 212 as a technical elective

→ = Prerequisite

→ = Prerequisite or Concurrent

Chapter 2: ESM Department Information

2. 1 —Statistics

E SC Majors: 86

E MCH Minors: 32

NANO Minors: 5

Graduate Students (M.S., M.Eng., Ph.D.): 107

ESM Faculty: 40

Research Laboratories and Centers: 30

2. 2 —ESM Faculty Areas of Current Research

Osama O. Awadelkarim, Ph.D. Professor of Engineering Science and Mechanics: Nano-fabrication, microelectronics materials & devices; power electronic devices; IC Processing; Defects in crystalline & polycrystalline semiconductor materials; Thin film transistors for active matrix liquid crystal display appls; MEMS & nanofabrication.

S. Ashok, Ph.D. Professor of Engineering Science: Electrical properties and applications of thin films. Semiconductor devices and materials. Microelectronics and semiconductor power electronics. Solid-state sensors. Photovoltaic energy conversion.

Charles E. Bakis, Ph.D. Distinguished Professor of Engineering Science and Mechanics: Composite materials, fatigue, fracture, damage development, residual strength, nondestructive evaluation, and micromechanics.

Francesco Costanzo, Ph.D. Associate Professor of Engineering Science and Mechanics: 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: Nonlinear dynamics and chaos in mechanical and electromechanical systems. Experimental methods in the dynamics of solids.

Melik C. Demirel, Ph.D. Pearce Assistant Professor of Engineering Science and Mechanics: Bio-molecular materials, microfluidics, biosensors, molecular modeling, computational materials science.

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

Renata S. Engel, Ph.D. Professor of Engineering Graphics and Engineering Science and Mechanics; Associate Dean for Undergraduate Affairs: Composites manufacturing and transport process modeling, dynamics and stability design in engineering education.

Stephen J. Fonash, Ph.D. Bayard D. Kunkle Chair Professor of Engineering Sciences; Director of the Center for Nanotechnology Education and Utilization: Thin-film properties and device applications; semiconductor device physics; microelectronics; solar cells, solid state sensors.

Lawrence H. Friedman, Ph.D. Assistant Professor of Engineering Science and Mechanics: Theory and computation of crystal microplasticity—dislocation dynamics; finite element method; metal matrix composites; multilayer protective coatings; nanostructures.

Bruce J. Gluckman, Ph.D. Associate Professor of Engineering Science and Mechanics and Associate Professor of Neurosurgery in the College of Medicine (Milton S. Hershey Medical Center); Associate Director Center for Neural Engineering: Electromagnetic theory, non-linear dynamics, chaos control, neuronal networks, and neural prosthetic devices.

Gary L. Gray, Ph.D. Associate Professor of Engineering Science and Mechanics: Nonlinear dynamics and stability of engineering systems. Spacecraft attitude dynamics. Nanomechanics of thin films and devices. Use of molecular dynamics simulations to predict mechanical properties at the nanoscale. Mechanics across length scales.

Robert E. Harbaugh, M.D. University Distinguished Professor of Neurosurgery and Engineering Science and Mechanics; Head, Department of Neurosurgery, Penn State University College of Medicine: Diseases and disorders of the brain, spinal cord and their supporting structures such as the spine, skull, skull base and carotid arteries.

Mark W. Horn, Ph.D. Associate Professor of Engineering Science and Mechanics: Plasma etching, thin film deposition, lithography, planarization, MEMS, gas sensors, and engineered thin films.

Tony J. Huang, Ph.D. James Henderson Assistant Professor of Engineering Science and Mechanics: Micro-electromechanical systems (MEMS) and BioNEMS, molecular mechanics and microfluids.

Akhlesh Lakhtakia, Ph.D. Charles Godfrey Binder Distinguished Professor of Engineering Science and Mechanics: Sculptured thin films; Complex mediums; Wave-material interaction; Electromagnetics; Composite materials; Chiral mediums; Anisotropic and bianisotropic mediums; Helicoidal bianisotropic mediums; Acoustics; Micropolar materials; Chaos and Fractals.

Michael T. Lanagan, Ph.D. Associate Professor of Engineering Science and Mechanics; Researcher/ Professor of Materials Science and Engineering, Associate Director of the Penn State Center for Dielectric Studies, and Associate Director of the Materials Research Institute: Development of new electronic materials for miniaturized wireless devices and electromagnetic property characterization of materials at microwave and mm-wave frequencies.

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. Associate Professor of Engineering Science and Mechanics: General area of solid mechanics. My work centers around experiments to validate constitutive relations. In particular, I am interested in elastic-viscoplastic material response, multiaxial stress effects, and damage accumulation.

Christine B. Masters, Ph.D. Assistant Professor of Engineering Science and Mechanics: Engineering education, instructional technology, and numerical modeling.

Robert N. Pangborn, Ph.D. Professor of Engineering Mechanics, Vice-President and Dean of Undergraduate Education: Nondestructive evaluation of fatigue damage and creep in metals and alloys. Characterization of defects and fracture in deformed single crystals. Structure and mechanical behavior of ceramics and photovoltaic device materials. Indentation and wear deformation. X-ray diffraction and topography.

Jean Landa Pytel, Ph.D. Associate Professor of Engineering Science and Mechanics, Assistant Dean of Student Services in the College of Engineering: Efficiency of human movement and movement interaction with work and sport environments. Engineering academic advising and University policies relating to undergraduate students.

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.

Steven J. Schiff, M.D., Ph.D., F.A.C.S. Professor of Neurosurgery in the College of Medicine (Milton S. Hershey Medical Center), Director for Center for Neural Engineering, Professor of Engineering Science and Mechanics and Brush Chair Professor of Engineering in the departments of Engineering Science and Mechanics, Neurosurgery and Physics: Pathological dynamics in the brain in terms of the underlying physics, and technology based treatment of Epilepsy and Parkinson's disease.

Albert E. Segall Ph.D. Associate Professor of Engineering Science and Mechanics: Wear, friction, coatings, and the development of realistic tribotest methods. Probabilistic fracture and brittle-design methodologies and their application to thermal shock and laser machining. Failure analysis. Computational design including finite-element methods. Engineering education. Implications of science, technology, and society.

Vladimir Semak, Ph.D. Associate Professor of Engineering Science and Mechanics; Senior Research Associate, Applied Research Laboratory: Industrial applications of lasers and research in the areas of laser-material interaction and plasma physics (i.e. experimental study of laser drilling and welding, theoretical and numerical modeling of laser welding and laser free forming, development of acoustic spectral systems, laser-induced plasmas, and theoretical and numerical modeling of laser supported detonation

Barbara A. Shaw, Ph.D. Professor of Engineering Science and Mechanics: Environmental degradation of engineering materials, stress corrosion cracking and coating to prevent degradation. Accelerated corrosion testing and evaluation.

Jogender Singh, Ph.D. Senior Scientist, Head of Advanced Coatings Division ARL and Professor of Material Science and Engineering: Nano-materials, thin films, coatings and surface engineering.

Ivica Smid, Ph.D. Associate Professor of Engineering Science and Mechanics: Tailoring, modeling and qualification of sintered high-performance materials, hard metals, and composites; non-destructive inspection; consolidation process optimization; rapid prototyping.

Bernhard R. Tittmann, Ph.D. Schell Professor of Engineering Science and Mechanics: Materials science and characterization, nondestructive evaluation techniques and applications, scanning acoustic microscopy/spectroscopy, physical acoustics, and ultrasonic characterization.

Judith A. Todd, Ph.D. P. B. Breneman Department Head Chair, Professor of Engineering Science and Mechanics: Bulk nanomaterials synthesis and manufacturing from highly non-equilibrium liquids; non-destructive evaluation of ceramic and ceramic matrix composite materials; creep of advanced ceramic and ceramic materials; laser materials interaction; sensors; non-destructive evaluation.

Mirna Urquidi-Macdonald, Ph.D. Professor of Engineering Science and Mechanics: Neural Networks data mining applied to (a) drug dose-effect pattern recognition; (b) heart beat to beat analysis; (c) electrochemical applications: life prediction of components, batteries, fuel cells, nuclear waste, and nuclear reactors.

Eduard Ventsel, Ph.D. Professor of Engineering Science and Mechanics: Numerical methods (boundary elements, finite elements), mechanics of solids, stability and dynamic analysis.

Jian Xu, Ph.D. Assistant Professor of Engineering Science and Mechanics: Semiconductor optoelectronic devices and circuits; bioelectronic and biophotonic devices; MicroOptoElectroMechanical Systems (MOEMS); molecular bioelectronic materials; light sensitive proteins, polymers; ultrafast tracking and motion detection; polarization-sensitive light detection; electro-optic modulators; semiconductor lasers and detectors.

Sulin Zhang, Ph.D. Assistant 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 research laboratories are housed in the *Earth-Engineering Sciences Building* on the West Campus. The ESM faculty also have laboratories in Hammond Building, the Materials Institute, 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 E SC 433H, research internships, and the senior research and design project, E SC 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, 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, humidity cabinet, alternate immersion tester, corrosion cells, class 1000 clean-room, 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 strain 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 of interest.

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 E SC 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 new 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:

1. For admission to the Engineering Science program, a student must show unusual academic promise.
2. 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.
3. 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 19 Honors credits will be accepted in satisfaction of Honors degree requirements.
4. Each student in the Honors program must complete a senior thesis. In Engineering Science, the report of the senior research and design project (E SC 410H and 411H) serves as the senior thesis. The thesis must be typed and submitted no later than one week before the last day of classes of the semester in which the student is registered for E SC 411H. The report is submitted in triplicate and each copy must be prepared according to Departmental regulations. One copy is for the Department, one is for the student's project adviser. The Schreyer Honors College receives an unbound copy for students graduating with a cumulative GPA of 3.2 or higher. Appendix D contains guidelines for the preparation of the thesis.
5. 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 E SC 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.
6. Each student will maintain a portfolio as described in section 4.7.
7. Engineering Science students must earn a minimum grade of C in the following required courses: E MCH 210H or 210 (or the combination of E MCH 211 and 213 or E MCH 211 and 213D), E MCH 212H or 212, E SC 404H, E SC 407H, and E SC 414M.
8. 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.
9. 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 3.20 or higher at the time of graduation.

10. 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 students in the Department elect two representatives to the Engineering Undergraduate Council, which speaks for the entire undergraduate student body of the College.

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, 865-6301. Financial need is an important factor in the selection criteria for most of the department's scholarships.

<http://www.psu.edu/studentaid/>

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, Kathleen Zimmerman, 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://elion.oas.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. This petition form is available in the Department office (212 Earth-Engineering Science). Petitions for exceptions to the AHS requirements will not be considered during a student's final semester.

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. The Council of Academic Deans statement describing academic integrity can be found at <http://www.engr.psu.edu/Forms/AcademicIntegrity/form.pdf>

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 <http://www.engr.psu.edu/CurrentStudents/acadinteg.asp>

3. 5 —Student's Academic File

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

1. a curriculum checklist for recording the courses completed
2. copies of the undergraduate transcript
3. copies of the various registrations, preregistrations, and degree audits
4. records of changes, petitions, etc.
5. other, such as co-op reports

This file is an official Department record and is retained by the Department.

3. 6 —Adviser's Checklist

To graduate, each student must satisfactorily complete all Department, College and University requirements. To keep track of progress, a checklist 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 checklists are revised accordingly. The proper checklist will be furnished by each adviser. (See *Appendix E* for a sample checklist). 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 at one place of one's academic and professional accomplishments, and thereby, provide hard evidence of the student's progression towards achieving professional level quality in their activities. This evidence will be used in two ways; 1) to supplement the department's records to assess the effectiveness of the program and 2) to evaluate the development of each student in achieving outcomes deemed essential to good engineering practice by ABET (Accreditation Board of Engineering and

Technology) who recognizes the creation and evaluation of such portfolios as a legitimate factor in student evaluation. The portfolio will clearly be an asset to faculty when writing letters of reference, providing information to potential employers, and granting of scholarships.

The portfolio of hard copies of representative work is kept on file in the Department office by the Assistant for Undergraduate Student Affairs. Additionally, electronic archiving of portfolio materials is being developed through the ANGEL system.

The materials that a student should consider for his/her portfolio can be any material that demonstrate achievement in four specific areas:

- design (see definition of design in the next section)
- communication (both oral and written)
- group work/leadership
- academic excellence

The student must meet with his/her academic adviser at least once per semester to discuss new entries so that the portfolio can be assessed on a continuing basis

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

1. A student may not add a course to his or her schedule after the first ten calendar days of a semester. (See Senate Policy 34-87 for exceptions).
2. A student may drop a course during the first ten calendar days of a semester. The student should consult with his/her adviser to discuss any ramifications of this action.
3. If a student is taking a course concurrently with a prerequisite course, the prerequisite course may not be dropped without also dropping the course for which it is a prerequisite.
4. A student may late drop a course beginning with the 11th day and ending on the last day of the 12th week. A WP (passing) or WF (failing) or WN (no grade) symbol will be entered on the student's academic record and transcript.
5. No student may drop a course after the last day of the 12th week for any reason.
6. Use of the late course drop from the beginning of the 11th day to the end of the 12th week of classes is limited to a maximum 16 credits for baccalaureate degree candidates.
7. A fee will be charged for each change of schedule filed after the seventh working day of the semester.

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 *Baccalaureate Bulletin*. A standard or normal schedule, as indicated by these outlines, includes 12 to 19 credits per semester.

Irregular Schedule

An adviser is authorized to approve irregular schedules that are necessary because of a student's transfer from another institution with advanced standing, change or major, failure in one or more courses, or extenuating circumstances beyond the student's control.

Heavy Schedule (Maximum Credit Load)

No student shall be permitted to be enrolled for more than a typical credit load (19 credits, Senate Policy 34-52; the credit value of an audited course is included in the credit load) in any one semester by all delivery systems without permission of the student's academic adviser. All credit courses scheduled regardless of delivery system must be approved by the student's adviser (Senate Policy 34-55).

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 (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 12th 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

All baccalaureate degree students must complete 49 credits of General Education. The General Education program reflects the belief of educators and leaders in all professions that successful, satisfying lives require a wide range of skills and knowledge. Skills courses teach the ability to reason logically and quantitatively and to communicate effectively. Other courses provide broad overviews of the world we live in. Courses that satisfy General Education requirements are designated with appropriate suffixes in the *Baccalaureate Bulletin*. Consult your *Bulletin* or the *General Education* brochure for specific details.

Arts courses emphasize the traditions, literature, and history of the arts and architecture that have served as an expression of the cultural values of society. They are designed to help students understand the approaches to human experience that distinguish the arts. The student may select courses from the following Arts divisions: interdisciplinary; architecture/landscape architecture; music, performance arts; and visual arts.

Humanities courses emphasize coherent overviews of cultural and intellectual currents, shaping or interpreting individual and social values. They relate major figures, ideas, achievements, and/or world-shaping events to the most enduring continuities in human experience. Humanities divisions include: interdisciplinary, history, language and literature, philosophy, and religion.

Social and Behavioral Sciences courses emphasize major concepts, findings, and analytic methods most useful to an informed citizenry that needs to understand politics, economic systems, social institutions, individual and group behavior, and human communication. Courses in this division include: interdisciplinary; anthropology and linguistics; economics, geography, mass communications; politics, government, and history; psychology and developmental studies; sociology.

The student may select from a wide range of courses to fulfill these requirements. The student's own judgment, interests, and curiosity will determine the courses to select. *There is no best course for an engineering student. There is only a best course for the student, and the student is the determinant of that. It is the student's responsibility to check the Bulletin to see if there are prerequisites for a course.*

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

Skills (18 credits required)

1. Writing/Speaking (12 credits)
ENGL 015 or 030
ENGL 202C
CAS 100A/B
Writing Intensive course (E SC 261Mor E SC 414M)
2. 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 GHS or GPE to satisfy this requirement.

Distribution Component (28 credits required)

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

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 002, 004, or 014. 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 of 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 E SC 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 6.1) and up to 3 ROTC credits as departmental technical electives.

Chapter 6: Schedule of Course Offerings

E MCH Course	Fall	Spring	Summer	E SC Course	Fall	Spring	Summer
E MCH 210	•	•		E SC 261M		•	
E MCH 210H	•			E SC 312	•		
E MCH 211	•	•	•	E SC 313		•	
E MCH 212	•	•	•	E SC 314	•	•	•
E MCH 212H		•		E SC 400H		•	
E MCH 213	•	•	•	E SC 404H	•		
E MCH 315	•	•	•	E SC 406H		•	
E MCH 316	•	•	•	E SC 407H	•		
E MCH 400	•			E SC 410H	•	•	•
E MCH 401	•			E SC 411H	•	•	•
E MCH 402		•		E SC 414H	•		
E MCH 403		•		E SC 417			
E MCH 407		•		E SC 419			
E MCH 409	•			E SC 433H	•		
E MCH 412		•		E SC 445		•	
E MCH 416H		•		E SC 450	•		
E MCH 440		•		E SC 455		•	
E MCH 461	•	•	•	E SC 456			
E MCH 471	•			E SC 475	•		
E MCH 473		•		E SC 481	•		
E MCH 496	•	•	•	E SC 482	•		
E MCH 497	•	•	•	E SC 483		•	
				E SC 484	•		
				E SC 496	•	•	•
				E SC 497	•	•	•

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 E MCH 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

1. 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.
2. 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.
3. Application procedure: Follow the detailed set of instructions in the above referenced *Co-op Student Handbook*.
4. Staff support (people to help you):
 - College Co-op Program Director
205 Hammond Bldg. (863-1032).
 - Engineering Science Co-op Coordinator:
Dr. Christine Masters
210 Earth-Engineering Sciences Building. (865-6674).

The Eight Steps

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 curricula 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:

<http://elion.oas.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 Sophomore Years	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall (Last Semester)
<i>Curriculum A</i>	IDENTICAL	WORK ENGR 295	E SC 312 3 E SC 407H 3 EE 210H 4 E SC 414M 3 AHS 3 <u>16</u>	WORK ENGR 395	AHS 3 ENGL 202C 3 GHS 3 <u>9</u>	WORK ENGR 495	M E 302 4 FE 3 FE 3 FE 3 FE 3 <u>16</u>	TE E SC 410H 3 E SC 410H 3 E SC 410H 3 E SC 410H 3 E SC 410H 3 <u>16</u>	AHS 3 E SC 404H 3 TE 3 TE 3 TE (ENGR 295,395,495) 3 E SC 411H 3 TECH LAB 1 <u>16</u>
<i>Curriculum B</i>	CURRENT	EE 210H 3 ENGL 202C 3 AHS 3 <u>9</u>	WORK ENGR 295	M E 302 4 FE 3 FE 3 FE 3 FE 3 <u>16</u>	WORK ENGR 395	E SC 407H 3 E SC 312 3 E SC 414M 3 AHS 3 GHS 3 <u>15</u>	WORK ENGR 495	TE TE E SC 410H 3 E SC 410H 3 E SC 410H 3 E SC 411H 3 TECH LAB 1 <u>16</u>	AHS 3 E SC 404H 3 TE 3 TE 3 TE (ENGR 295,395,495) 3 E SC 411H 3 TECH LAB 1 <u>16</u>
<i>Curriculum C</i>	PROGRAMS	ENGL 202C 3 AHS 3 AHS 3 <u>9</u>	E SC 312 3 E SC 407H 3 AERSP 308 3 EE 210H 4 E SC 414M 3 <u>16</u>	WORK ENGR 295	AHS 3 TE 3 GHS 3 <u>9</u>	WORK ENGR 395	M E 302 4 FE 3 FE 3 FE 3 E SC 410H 3 <u>16</u>	WORK ENGR 495	E SC 404H 3 TE 3 TE 3 TE (ENGR 295,395,495) 3 E SC 411H 3 TECH LAB 1 <u>16</u>

TE = Technical Elective
FE = Foundational Elective

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

Introduction

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. (2) 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 Schreyer 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

1. IUG proposals may be filed by Engineering Science students holding at least fifth semester standing with a GPA of 3.4 or better.
2. The application for IUG status consists of the following materials, all of which should be submitted to the ESM IUG Selection Committee through the ESM Undergraduate Officer in 212 EES Building.
 - a. A nomination from the head or graduate officer of the ESM department.
 - b. 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.
 - c. An explicit plan of study leading to the graduate degree (form available in the ESM departmental office) signed by the Honors adviser. NOTE: As many as 12 of the credits required for the master'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.
 - d. Three faculty recommendations including one from the Honors adviser and one from the prospective research mentor for the master's program or a faculty member expert in the proposed area of graduate research concentration. The latter must address the details of the proposed area of research focus and assess the student's ability to conclude the program.
 - e. A transcript.
 - f. A completed Graduate School application form. GRE scores need not be submitted.

When all materials have been submitted, the applicant should schedule an interview with the ESM Undergraduate and Graduate Officers to discuss her or his IUG proposal.

After this interview, an evaluation of the application is made by the ESM IUG Advisory committee. The committee will look for (a) an undergraduate record which is superior, even among Engineering Science students; (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 Engineering Science students; (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.

3. Applicants are notified of the action of the committee. If the application has been approved by the ESM IUG Committee, it is sent to the Graduate School for approval. The Graduate School application fee must be sent along with the application.
4. When a candidate has been approved for IUG status by both the Engineering Science Department and the Graduate School, he or she will receive a letter of notification from the director of graduate admissions.
5. At the end of each semester, a student with IUG status must report to the ESM Undergraduate Officer which courses taken that semester are to be counted both toward the graduate and undergraduate degrees or toward the graduate degree alone. A form for such reporting is available in 212 EES Building.

6. 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.
7. 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 the 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(c), 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 that degree
8. An appropriate notation of participation in the Integrated Undergraduate Graduate program will be made on the student's transcript.
9. Undergraduate tuition rates will apply as long as the student is an undergraduate, unless the student receives financial support, for example, an assistantship requiring the payment of graduate tuition.

SHC IUG Application Procedures and Guidelines

1. IUG proposals may be filed by Engineering Science students holding fourth, fifth, or sixth semester standing. Students in their senior year are ineligible to apply.
2. The application for IUG status consists of the following materials, all of which should be sent to the Schreyer Honors College, 10 Schreyer Honors College (Atherton Hall).
 - A nomination from the head or graduate officer of the major department (one from the head of the undergraduate department and one from the head or graduate officer of the graduate program if the undergraduate and graduate programs are different).
 - 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.
 - An explicit plan of study leading to the graduate degree (form available in the Schreyer Honors College) signed by the Honors adviser. NOTE: As many as 12 of the credits required for the master'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 Honors adviser and one from the prospective research mentor for the master's program or a faculty member expert in the proposed area of graduate research concentration. The latter must address the details of the proposed area of research focus and assess the student's ability to conclude the program.
 - A transcript.
 - A completed Graduate School application form. GRE scores need not be submitted, unless

required by a particular graduate program.

When all materials have been submitted, 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.

3. 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.
4. 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.
5. 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 undergraduate degrees or toward the graduate degree alone. A form for such reporting is available in the Schreyer Honors College office.
6. 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.
7. 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.
8. An appropriate notation of participation in the Integrated Undergraduate Graduate program will be made on the student's transcript.

APPENDIX C: Minors

I. I —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 E SC 312 and E SC 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
- E SC 419 Electronic Properties and Applications of Materials
- E SC 481 Elements of Nano/Micro-electromechanical System 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

For more information on the undergraduate Nanotechnology Minor, contact:

Christine B. Masters, Ph.D.
Undergraduate Program Coordinator
The Pennsylvania State University
212 Earth and Engineering Sciences Building
University Park, PA 16802-6812

Tel: 814-865-6674

E-mail: cbm100@engr.psu.edu OR
undergraduateofficer@email.esm.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 unequibrated 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, automotive, 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 E MCH course counted toward 18-credit minimum.
- Students majoring in Engineering Science may apply the three credits of E SC 407H toward the E MCH minor as this course is deemed to cover the E MCH type material of E MCH 407.

Admission Requirements

Applicants wishing to enroll in the Engineering Mechanics Minor should have completed a background 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. Application forms may be obtained from the Engineering Science Assistant for Undergraduate Student Affairs (Kathleen Zimmerman, 212 Earth-Engineering Sciences Building, 865-4523) on the web at: http://www.psu.edu/registrar/forms_for_students/entrancetominor.pdf.

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

undergradofficer@mail.psu.edu
 Room 212 Earth-Engineering Sciences Building
 University Park, PA 16802

APPENDIX D: Guidelines for Thesis Preparation and Submittal

1. Prepare an outline of the thesis and clear it with your supervisor prior to attempting a first draft. Please refer, for example, to J. Schall's book *Style for Students' Effective Writing in Science and Engineering*, Burgess Pub. (1995), pp. 23-28.
2. 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/thesis/writing.htm>.

APPENDIX E: Undergraduate Checksheet

See next page for E SC graduation checksheet.

STUDENT NAME: _____

ADVISOR: _____

✓ 1 st Semester	Cr	Sem	✓ 2 nd Semester	Cr	Sem
ENGL 15 / 30	3		FOUNDL ELEC	3	
EDSGN 100	3		FY Seminar	1	
MATH 140	4		MATH 141	4	
ECON 2 / 4 / 14	3		E SC 261M or CMPSC 201 or CMPSC 202	3	
CHEM 110	3		PHYS 211	4	
			CHEM 111	1	
	16			16	

✓ 3 rd Semester	Cr	Sem	✓ 4 th Semester	Cr	Sem
^c E MCH 210H	5		^c E MCH 212H	3	
MATH 220	2		MATH 251	4	
MATH 230	4		AHS	3	
PHYS 212	4		PHYS 214	2	
AHS	3		CAS 100	3	
	18			15	

✓ 5 th Semester	Cr	Sem	✓ 6 th Semester	Cr	Sem
^c E SC 414M	3		FOUNDL ELEC	3	
^c E SC 407H	3		FOUNDL ELEC	3	
AHS	3		FOUNDL ELEC	3	
E E 210H	4		FOUNDL ELEC	3	
E SC 312	3		M E 302	4	
E SC 433H	1				
	17			16	

✓ 7 th Semester	Cr	Sem	✓ 8 th Semester	Cr	Sem
ENGL 202C	3		TECH ELEC	3	
^c E SC 404H	3		TECH ELEC	3	
E SC 410H	3		E SC 411H	3	
TECH ELEC	3		AHS	3	
TECH ELEC	3		AHS	3	
GHS	1.5		GHS	1.5	
	16.5			16.5	

Total Number of Credits - 131

- ✓ Course has been successfully completed
- ^c A minimum grade of C is required for graduation.

Note: E SC 414M (or E SC 261M) fulfills the Writing Across the Curriculum requirement.

Pending satisfactory completion of current courses, this student is certified to have met all the requirements of the Engineering Science curriculum.

(Academic Advisor's Signature)

(Date)

FOUNDATIONAL ELECTIVES

List A [^]	List B
CHEM 112	_____
AERSP 308	_____
E MCH 416H	_____
E SC 400H	_____
E SC 419	_____

[^] Must select at least 3 courses from List A

TECHNICAL ELECTIVES

	Engineering Science (3 credits min.)	Engineering Design (2 credits min.)
_____	_____	_____
_____	_____	_____
_____	_____	_____
_____	_____	_____

AHS and CULTURES REQUIREMENTS

Arts (GA) - 6 cr⁺

Humanities (GH) - 6 cr⁺

Social & Behavioral Sciences (GS) - 6 cr⁺

⁺ Students may develop a 9-6-3 sequence

US Cultures (US)

International Cultures (IL)

CO-OP CREDITS

ROTC CREDITS

Thesis Title _____

Thesis Advisor _____

The baccalaureate program in Engineering Science and Mechanics is accredited by the
Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology
111 Market Place
Baltimore, MD 21202-4012
410.347.7000

