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College of Engineering

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Engineering Science and Mechanics

Graduate Programs Guide

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Chapter 1: General Information

1.1-SARI

As part of the AMERICA Competes Act of 2007, the Federal Government is now requiring all graduate students to receive training in the responsible conduct of research.

During their first semester all new incoming COE graduate students will be required to complete an online Responsible Conduct of Research (RCR) training program provided by the Collaborative Institutional Training Initiative (CITI). The Office for Research Protections (ORP) will provide the link to this training via the (Scholarship and Research Integrity) SARI Resource Portal on the ORP website (www.research.psu.edu/orp) or at SARI@PSU website (<http://www.research.psu.edu/education/sari>). Once completed, a printable certificate will be available that must be shown to the ESM Academic Affairs Manager to verify completion.

For all ESM Students, the second part of the SARI program will be completed through the required seminar series (E SC/E MCH 514) where at least 5 hours of RCR (Responsible Conduct of Research) seminars and discussions will be held over the course of the credits required for either MS or PhD degrees.

It is important to note that your involvement in this program will give you important and marketable skills that employers will seek. Hence, in addition to learning valuable coursework and skill sets related to research and its ethical conduct, you will be learning professional skills highly sought by employers in industry, government, and academia.

1.2-ESM Academic Integrity Policy

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

Academic dishonesty includes, but is not limited to, cheating, copying on tests, plagiarizing (**copying anything without proper citation(s)**), acts of aiding or abetting, unauthorized possession of materials, tampering with work, ghosting, altering examinations and theft. Students are encouraged to report incidents of academic dishonesty to their instructors in order to promote a fair academic climate and an 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 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:



1.3-Policy SY01: Environmental Health and Safety Policy

PURPOSE:

The Pennsylvania State University is committed to protecting the health and safety of its employees, students, visitors and the environment. The purpose of this document is to establish an organizational structure to ensure the effective implementation of this policy at all University locations.

POLICY:

All employees, students and visitors are expected to comply with the statements that follow. Each department or unit shall supplement this policy document with specific procedures about hazards in their workplace and the precautions necessary to control and prevent these hazards. These supplements, prepared in cooperation with the Office of Environmental Health and Safety, may be in the form of written procedures and/or training programs.

The responsibility for the administration of the University's health and safety program is assigned to the Office of Environmental Health and Safety. Implementation of this policy is the responsibility of the entire University community - staff, faculty and students.

The University Safety Council, with members representing the University's academic colleges and administrative units, is responsible to identify needs, develop procedures, and assist in the implementation of environmental health and safety programs under the direction of the Office of Environmental Health and Safety.

Applicable federal and state laws and regulations, together with policies and procedures issued by or through the office of Environmental Health and Safety, will provide the guidance under which the University will conduct its safety program.

Employees and Students:

1. All University employees and students have specific responsibilities to comply with established health and safety policies, standards, rules, procedures and regulations. Compliance with these is essential to create and maintain a healthy and safe environment at all University locations.
2. All persons working in a laboratory **MUST** complete the Environmental Health and Safety (EHS) Laboratory Safety Training. This training is found at www.ehs.psu.edu;
Training Courses and Registration;
EHS On-line Course Registration;
Laboratory Safety
3. Comply with applicable environmental health and safety policies, standards, rules, regulations and procedures. These include safety-related signs, posters, warnings and written/oral directions when performing tasks.
4. Do not perform any function or operation which is considered hazardous, or is known to be hazardous without proper instructions and authorization.

5. Only use equipment and materials approved or provided by the supervisor or instructor and for which instruction has been provided by this or other experience.
6. Become thoroughly knowledgeable about potential hazards associated with the work area; knowing where information on these hazards is maintained and how to use this information when needed.
7. Wear or use prescribed protective equipment.
8. Report all unsafe conditions, practices, or equipment to the supervisor, instructor or safety officer whenever deficiencies are observed.
9. Inform the supervisor or instructor immediately of all work-related injuries or accidents and obtain prompt medical attention when necessary.
10. Provide information necessary for the supervisor or safety officer to adequately and thoroughly complete the *Employer's Report of Occupational Injury and Illness* and any other associated accident/illness reports.

Graduate Study in Engineering Mechanics and in Engineering Science and Mechanics Degrees Awarded

Master of Engineering

Engineering Mechanics (M ENG/ E MCH)

Master of Science

Engineering Science and Mechanics (M.S./ESMCH)

Engineering at the Nano-scale

Doctor of Philosophy

Engineering Science and Mechanics (Ph.D./ESMCH)

1.4-Programs

Programs leading to M.S., M.ENG., and Ph.D. degrees allow specialization in research areas such as biomechanics; bionanotechnology; composite materials; fracture mechanics; continuum mechanics; electrical-magnetic-mechanical properties of thin films; experimental mechanics; MEMS; micromechanics; neural engineering; numerical methods; photovoltaic materials and devices; microelectronics materials and devices; nanotechnology; properties of materials, shock, vibration, acoustics and nonlinear dynamics; structural mechanics; wave/materials interactions; non-destructive evaluation; microfluidics; neurosurgery, neuroscience and failure analysis.

A student working for a master's degree may pursue either a Master of Science or Master of Engineering program. For the Master of Science degree of Engineering Science and Mechanics, a minimum of 32 graduate credits (including 6 credits of thesis research) is required. A candidate for the Master of Science degree is required to submit a thesis to the University.

The Master of Engineering degree in Engineering Mechanics is based primarily on graduate lecture course work. At least 30 credits of 400/500 level coursework must be completed by M ENG candidates for graduation. The student is also required to submit to the department a scholarly written report on a developmental study involving at least one area represented in his or her course work. This report must be comparable in the level of work and quality to a graduate thesis.

The Doctor of Philosophy degree in Engineering Science and Mechanics does not have strict course requirements beyond 27 graduate credits after a Masters (including 6 credits of thesis research). If starting the program with a Bachelors degree, Ph.D. students must earn a minimum of 42 credits in course work and five credits of graduate seminar. Acceptance into Ph.D. candidacy is by examination and admission only. A student may be admitted to the Graduate School and the department to begin working toward a Ph.D.; however, he or she has no assurance of becoming a Ph.D. candidate until the candidacy examination has been passed and candidacy admission has been granted. The candidacy examination must be taken for the first time within two semesters of residency.

After admission to the candidacy, Ph.D. students have their work supervised by a committee of the graduate faculty. This doctoral committee plays a major role in determining the candidate's specific course requirements. The committee also administers the candidate's comprehensive and final oral thesis examinations, and guides the candidate's thesis work that must represent a significant contribution to the body of knowledge in a given area.

The Graduate School requires the student to have a high level of competence in the reading, writing, listening, and speaking of English before admission to candidacy. Proficiency is expected at the time of admission to the Graduate School.

1.5-Admission

Students are admitted to the Graduate School by the University examiner, following favorable recommendation by the Graduate Officer and Graduate Admissions Committee. Procedures to be followed are outlined in the Penn State Graduate Degree Programs Bulletin.

A new policy was introduced effective July 5, 2012. HR 99 Background Check Process calls for all new hires to undergo a background check. New hires must complete the background check process before working for Penn State. One important new requirement is that “all individuals engaged by the University, including those engaged prior to, as of, or after, the effective date of this policy, to self-disclose criminal arrests and/or convictions as outlined in the Penn State Arrest and Conviction self-disclosure form within a 72-hour period of their occurrence” Please take the time to review the entire policy at <http://guru.psu.edu/policies/OHR/hr99.html>

The minimum departmental requirements for admission to graduate standing (for both master’s and doctoral degrees) are:

A baccalaureate degree from an approved institution, either in an accredited engineering curriculum or in other programs in mathematics, the physical sciences, or engineering sciences is considered adequate to qualify the student for professional engineering activity.

The Engineering Science and Mechanics (ESM) Department has cooperative agreements with the undergraduate programs in Physics at the Millersville University of Pennsylvania, Edinboro University of Pennsylvania, Lock Haven University of Pennsylvania, Lebanon Valley College, and the Rose-Hulman Institute of Technology. *While these agreements do not guarantee acceptance into the graduate program, they do create a streamlined path for acceptance and transfer of undergraduate credits beyond those required for the B.S. degree.* Students who successfully complete a Bachelor of Science degree in Physics may elect to transfer up to 6 credits of 400-level courses in either physics or mathematics towards a Master of Science (M.S.) degree in the ESM Department provided the credits subject to transfer are above and beyond those required for the applicant’s undergraduate degree. Such students may also undertake summer research in ESM for credit which may be applied towards the M.S. ESMCH degree. Undergraduate students from the ESM Department are strongly encouraged to consult with the ESM Graduate Officer during their junior year of studies; for complete admission details please contact the ESM Graduate Officer.

For regular admission, Engineering Science and Mechanics requires that a student’s grade point average for the junior and senior undergraduate years must be 3.00 or better.

Provisional admission may be granted in special circumstances, i.e. baccalaureate degree not yet conferred, grades for the current semester not yet available, etc. Provisional admission is a temporary classification in which an applicant may remain for a period no longer than the first semester following admission, or the time it takes to accrue 15 credits, whichever comes first. Such admission is subject to cancellation if, upon arrival of the outstanding documents, the credentials do not meet the requirements for admission.

In some instances, credits may be transferred from a Penn State bachelor's program or from an external institution. Questions concerning credit transfers should be addressed to the ESM Graduate Officer. The application procedure is described at <http://www.esm.psu.edu/programs/graduate/application>. The main part of the application has to be submitted electronically (via the web), along with the current application fee of \$65.00. Please check the value online as it may change. **Engineering Science students please contact the ESM department regarding the application fee. The following items must be uploaded through the online application process on the Graduate School Website:**

1. **One (1) Official** transcript of all previous college/university course work. International applicants must submit official records, or attested copies, with certified translations if the records are not in English; please note that notarized copies are not acceptable. **The official transcripts must be sent to The Graduate School, not to the department.**
2. Statement of Objectives: Tell us why you want to pursue an advanced degree in Engineering Science and Mechanics and how it will help you to further your career objectives. Usually, one page is sufficient.
3. General Graduate Record Examination (GRE) Aptitude Test (verbal, quantitative, and analytical) - Codes: PSU 2660, ESM 1605 (official score report must be submitted by ETS®).
4. Test of English as a Foreign Language (TOEFL) score (for international applicants whose native language is not English, regardless of previous academic training). - Codes: PSU 2660, ESM 69 (official score report must be submitted by ETS®).
5. Three (3) letters of recommendation (on business or personal stationary with an authors' signature). ***We do not use recommendation forms.***
6. Application for Visa document (International students only):
<http://www.international.psu.edu/iss/pdf/VisaApp.pdf>

1.6-Scholarship

A minimum grade-point average of 3.00 for graduate work done at this University is required for graduation.

Grades are assigned solely on the basis of the instructor's judgment of the student's scholarly attainment. A "D" grade is considered a failing grade in a graduate course. While a "C" grade is considered passing, it is indicative of barely acceptable performance and may lower the GPA below the minimum grade-point average of 3.00 required for graduate work.

It is important to note that there are only three circumstances under which a course grade, once assigned, can be changed: (1) if there was a calculation or recording error on the instructor's part in the original grade assignment (Senate Policy 48-30), (2) if it is a course for which an R grade has been approved and in which an initial R can be assigned and changed later to a quality grade, or (3) if, as discussed below in section 1.5, a deferred grade (DF) was assigned and the deadline for course completion has not yet passed.

Students must maintain a minimum grade-point average of 3.00 to be eligible for a graduate assistantship or an instructorship. A graduate student with a grade-point average less than 3.00 is automatically put on academic probation and is required to meet the ESM Graduate Officer within the next two weeks.

Full-time master's degree students (including students receiving half-time support) should earn their degrees within two years; all required course work can be completed in 3 semesters. When available, financial support as a Teaching Assistant (TA) is ordinarily limited to no more than two semesters. ***Students are expected to quickly find a thesis adviser and be supported as a Research Assistant (RA).***

Full-time Ph.D. students (including students receiving half-time support) should earn their degrees in three years or less after successful completion of the candidacy examination; if they exceed this time period, financial support may be terminated. ***Students are expected to quickly find a thesis adviser and be supported as a Research Assistant (RA).***

1.7-Registration

Continuous registration is required for all graduate students.

E MCH/E SC 601/611—This special registration may be used only by Ph.D. students starting with the semester after the comprehensive examination is passed. If a student must maintain full-time status for an assistantship, fellowship, bank loan, deferment, etc., 601 would be an appropriate registration. Students in 601 must devote their efforts entirely to thesis research and writing (i.e., no courses). Students registered for 601 may take up to three credits for audit with no additional charge or three credits for credit with an additional flat fee.

E MCH/E SC 600/610—If the student does not need to maintain full-time status, he/she should register for the appropriate number of thesis credits that accurately reflect the amount of research being done on the thesis (number of credits are to be determined in consultation with the student's adviser).

Graduate students may not drop a course without the approval of the academic adviser and the Graduate Officer. Students must satisfy the minimum course credit requirement to retain their assistantship as detailed on the "Terms of Offer."

1.8-Deferred Grades

If work is incomplete at the end of a semester because of extenuating circumstances, the instructor may report Deferred (DF) in place of a grade, which will appear temporarily on the student's record. It is not appropriate to use the DF either casually or routinely to extend a course beyond the end of the semester or to extend a course for a student who has failed so that the individual can do extra work to improve the grade. ***The DF must be removed (i.e., the course must be completed) no later than 25 weeks after the course end date or it will be automatically changed to an F if the 25 weeks are exceeded.*** Instructors are not required to allow the full 25 weeks to elapse.

No deferred or missing grade may remain on the record once a student has completed a M.S. program and the doctoral candidacy, comprehensive, and final oral examinations. Graduate programs may add additional benchmarks.

As already discussed, a course grade can be changed if a DF was assigned and the deadline for course completion has not yet passed.

Chapter 2: Master's Degree in Engineering Science and Mechanics

The Department of Engineering Science and Mechanics offers a number of degree programs including: Masters of Science of Engineering Science and Mechanics (MS ESMCH), Masters of Engineering in Mechanics (ME EMCH) and Masters of Science in Engineering at the Nanoscale. There are one-year and two-year tracks for the MS ESMCH.

A student beginning graduate work should immediately seek a research adviser and quickly begin the research that is required for the degree. Until a research adviser is found, the graduate officer will assist the student in selecting courses, planning a preliminary program of study, and answering any questions about the ESM Department, Graduate Program, and Graduate School. The candidate should feel free to approach any faculty member for advice and counsel, as well as to discuss potential research projects for their thesis. This process should start on Day One and continue in earnest until an adviser is found, otherwise, there may be significant delays in the research, graduation, and/or possible loss of financial support.

2. 1-Overview of Master of Science Degree (MS ESMCH)

A comparison of the 2-year and 1-year MS ESMCH tracks is shown in Table 2.1. The 2-year Master of Science Degree (M.S.) in Engineering Science and Mechanics requires a total of 32 credits, including 2 credits of seminar and 6 credits of thesis research, culminating in a written thesis with oral defense. This track typically requires at least four semesters to complete. The 1-year track is aimed at preparing tomorrow's engineers in a very broad sense and is structured so that resident, full-time, students can complete the degree in 12 months. The 1-year track requires a minimum of 32 course credits, including two seminar credits and 3 credits of a residential research experience and a scholarly paper. This interdisciplinary program is ideal for individuals with a bachelor's degree in physics, engineering, mathematics, or related fields who wish to gain a deeper knowledge of engineering science and mechanics fundamentals and applications and to explore research opportunities.

Table 2.1: Proposed Degree Requirements

	Two Year M.S. thesis Track	One Year M.S. Thesis Track
Total number of course credits	24	27
Recommended number of semesters	4 (2 fall and 2 spring)	3 (fall, spring, summer)
Minimum number of E SC/E MCH credits	12 Including E MCH 524A	12 Including E MCH 524A
Maximum number of credits at 400 level	6	6
Core courses required	One mathematics course plus one from each category: materials, mechanics, engineering science (see Table 2.2) 12 credits	One mathematics course plus one from each category: materials, mechanics, engineering science (see Table 2.2) 12 credits
Graduate seminar (E SC/E MCH 514)	2	2
Research credits towards M.S. degree	E SC/E MCH 600 6 credits ¹	E SC/E MCH 596 3 credits
Culminating experience	Completion of research thesis and oral defense	Completion of a written scholarly paper and presentation
Total credits	32	32

¹ M.S. students are allowed a maximum of 6 credits of letter grades for 600 level courses.

2.1.1 - MS ESMCH Two Year Track

The two-year track Master of Science Degree in Engineering Science and Mechanics requires a total of 32 credits, including 2 credits of seminar and 6 credits of thesis research, culminating in a written thesis with oral defense. This track typically requires at least four semesters to complete.

The thesis required for the Master of Science degree in Engineering Science and Mechanics must be a well-organized account of research on an appropriate topic. In this research, the student must show initiative and originality and not merely carry out a routine test or investigation.

The thesis must contain a nontechnical abstract as the last appendix to explain the contributions reported in the thesis in terms that members of the general public may understand.

The M.S. thesis will be examined by a master's committee consisting of three faculty members, including the thesis adviser, and approved only after a satisfactory oral examination.

It is the responsibility of the student to arrange the time and date of the examination and to deliver a draft of his or her thesis to each member of the committee at least two (2) weeks prior to the thesis defense.

A master's candidate is not required to register for the final semester in order to graduate or in order to make minor revisions to the thesis and/or take a final examination for the degree.

A completed and signed thesis (electronic uploaded) must be submitted to the Graduate School by the deadline set by the Graduate School. Prior to commencement, the student must deliver two copies of their thesis, bound in accordance with the Graduate School requirements, to the ESM department office. The department head must sign the signatory page prior to binding.

The thesis defense is an important part of the degree and is open to the public. While each examination is related primarily to the thesis, the student can be asked other related/relevant questions. Moreover, the thesis presentation should emulate the presentation of a paper at a technical session of a national professional meeting. Specifically, the thesis defense should follow the 5 basic guidelines provided below:

1. It should be presented within a definite time period—approximately 20 – 30 minutes for an M.S.
2. The talk should be rehearsed with the actual visual aids prior to the presentation in order to comply with the time limitations.
3. As it is unlikely that a visual aid can be covered in less than one (1) to one and one-half (1½) minutes, a maximum of 20 – 25 visual aids is recommended.
4. The presentation should proceed without interruption from the audience.
5. Questions to the examinee must be answered by the examinee (i.e. not the thesis adviser).

It is important to note that an excessively long presentation may be rejected by the committee. Examinees should address the novel and challenging aspects of their research contributions. The thesis must contain a nontechnical abstract in addition to a technical abstract.

When the student delivers the thesis draft to each member of their master's committee, dates for the thesis defense should be determined. The thesis must be delivered to each committee member a minimum of two weeks before the day of the defense.

The unbound thesis must be submitted electronically via ETDs <http://www.etsd.psu.edu/> to the Graduate School by the deadline set by the Graduate School. Prior to commencement, the student shall deliver to the department office two acceptable copies of their thesis (one copy for the department file and the other for the adviser), bound in accordance with the requirements detailed in the Graduate School's Thesis Guide. The Thesis Guide is available on the Graduate School web site at: <http://www.gradsch.psu.edu/current/thesis.html>.

Costs incurred for thesis binding are the responsibility of the student. ***Reminder: The department head must sign the signatory page prior to binding.***

Course Requirements for the Two Year Track Master of Science in Engineering Science and Mechanics

Course credit requirements for the Master of Science degree in Engineering Science and Mechanics (MS ESMCH) are relatively straightforward as follows:

32 total credits, of which 24 are 3-credit 400/500 level classes in engineering/math/science, 6 are research credits (600 level), and 2 are seminar (E MCH/E SC 514).

Of the 24 course credits, 12 must be from the ESM department and have an E MCH or E SC prefix; dual listed courses will count as long as one of the listings is from ESM. A maximum of 6 credits at the 400 level are allowed; any increase beyond the six (6) 400-level credits must be approved by the ESM graduate officer via a petition. Seminar credits cannot be used to satisfy general course requirements.

Specific course requirements for the two year track Master of Science degree in Engineering Science and Mechanics (MS ESMCH) are as follows:

1. E MCH 524A is required; if a student took 404H as an E SC undergraduate, then another high level math such as E MCH 524B may be substituted.
2. At least one course from each of the categories Mechanics, Materials, and Engineering Science must be taken as summarized in Table 2-2.
3. 2 seminars (E MCH/E SC 514) and 6 Thesis Research (600 level) credits are also required.
4. The remaining course credit requirements may be taken at the discretion of the student and their academic/thesis adviser provided they satisfy the requirements of Table 2-1.
5. Please note that the categories Engineering Science, Mechanics, and Materials were selected to give the students breadth and depth and encompass both 400 and 500 level courses.

In order to provide a wide selection, many courses are from outside the ESM Department and some are listed in more than one category.

2.1.2 - MS ESMCH One Year Non-Thesis Track:

The one-year M.S. non-thesis track also requires a minimum of 32 course credits, including two seminar credits and 3 credits of a residential research experience and a scholarly paper. The focus of the 1-year degree is on full-time resident students. It is expected to appeal to engineers and scientists interested in a variety of fields such as, but not limited to aerospace, agricultural and biological, architectural, biomedical, civil, mechanical, nuclear, and petrochemical engineering, engineering mechanics, engineering science, materials science, physics, chemistry, biology and medicine.

In the first week of the fall semester, non-thesis M.S. students will receive information from the ESM Graduate Officer and/or the MS ESMCH Program Director about faculty research activities within the ESM department. They will be assigned a research advisor in the first semester so selection and discussion of the student's research project can begin as soon as possible. The paper must demonstrate the student's capability to integrate and apply concepts and techniques learned in the courses and thereby demonstrate the scientific, technical and ethical knowledge needed to practice engineering.

An electronic copy of the approved culminating research paper must be submitted to the ESM department at least two weeks before the end of summer classes. Students who need more time to complete the final paper may extend the submission due date after the third semester (summer). The degree will be granted after the paper has been reviewed and approved, and all degree requirements have been met. Students are not required to remain in residence while they complete the final paper.

However, extensions granted to students in this program must comply with the [Graduate Council policy on deferred grades](#). Subject to permission of the author, this paper will be posted on the department web site and will be available to interested persons.

Core Course E MCH 524A: All M.S. students are required to take a graduate level applied mathematics course. If a student has taken E SC 404H, then another high level mathematics course such as E MCH 524B may be substituted.

At least one course from each of the categories A) Mechanics, B) Materials, and C) Engineering Science must be taken as summarized in Table 2.

2 seminars credits (E MCH/E SC 514) and 3 credits of E SC/E MCH 596 Independent Study are also required.

The remaining course credit requirements may be taken at the discretion of the student and their academic adviser provided they satisfy the requirements of Table 2.

Table 2-2: Course Designations for Mechanics/Materials/Engineering Science

Mechanics:		
Mechanics is interpreted in its broadest context to include biomechanics, celestial mechanics, computational mechanics, fluid mechanics, quantum mechanics, solid mechanics, statistical mechanics, structural mechanics, and wave mechanics, among others).		
E MCH	400	Advanced Strength of Materials and Design
E MCH	402	Applied and Experimental Stress Analysis
E MCH	403	Strength Design in Materials and Structures
E MCH	407	Computer Methods in Engineering Design
E MCH	409	Advanced Mechanics
E MCH	416H	Failure and Failure Analysis of Solids
E MCH	440	Nondestructive Evaluation of Flaws
MATSE	440	
E MCH	446	Mechanics of Viscoelastic Materials
E MCH	461	Finite Elements in Engineering
E MCH	470	Analysis and Design in Vibration Engineering
E MCH	471	Engineering Composite Materials
E MCH	473	Composites Processing
AERSP	473	
E MCH	500	Solid Mechanics
E MCH	506	Experimental Stress Analysis3.0
E MCH	507	Elasticity
E MCH	516	Mathematical Theory of Elasticity
E MCH	520	Advanced Dynamics
E MCH	521	Stress Waves in Solids
E MCH	523	Ultrasonic Nondestructive Evaluation
E MCH	524B	Mathematical Methods in Engineering
E MCH	524C	Mathematical Methods in Engineering

E MCH	530	Mechanical Behavior of Materials
E MCH	532	Fracture Mechanics
E MCH	533	Scanned Image Microscopy
E MCH	534	Micromechanisms of Fracture
E MCH	535	Deformation Mechanisms in Materials
E MCH	536	Thermal Stress Analysis
E MCH	540	Introduction to Continuum Mechanics
E MCH	541	Structural Health Monitoring
E MCH	560	Finite Element Analysis
E MCH AERSP M E	571 571 571	Foundation of Structural Dynamics and Vibration
E MCH	581	Micromechanics of Composites
E MCH	582	Metal Matrix Composites
E SC	481	Elements of Nano/Micro-Electromechanical Systems Processing and Design
E SC	482	Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics
E SC	536	Wave Propagation and Scattering
BIOE	505	Bioengineering Mechanics
BIOE	510	Biomedical Applications of Microelectromechanical Systems (BioMEMS) and Bionanotechnology
BIOE	515	Cell Mechanics and Biophysics
BIOE I E	552 552	Mechanics of the Musculoskeletal System
BIOE I E	553 553	Engineering of Human Work
PHYS	410	Introduction Quantum Mechanics I
M E	555	Automatic Control Systems
M E	564	Elastic and Dynamic Stability of Structures
M E	580	Advanced Dynamics of Machines
M E	582	Mechanism Synthesis
AERSP	506	Rotorcraft Dynamics
AERSP	518	Dynamics and Control of Aerospace Vehicles
AERSP	550	Astroynamics
CHEM	565	Quantum Chemistry I

Materials: Select at least one course from the following list; each is a 3-credit course.

E MCH	402	Applied and Experimental Stress Analysis
E MCH	416H	Failure and Failure Analysis of Solids
E MCH	440	Nondestructive Evaluation and Flaws
E MCH	446	Mechanics of Viscoelastic Materials
E MCH	471	Engineering Composite Materials
E MCH AERSP	473 473	Composites Processing
E MCH	506	Experimental Stress Analysis
E MCH	530	Mechanical Behavior of Materials
E MCH	534	Micromechanisms of Fracture
E MCH	535	Deformation Mechanisms in Materials

E MCH	582	Metal Matrix Composites
E SC	414M	Elements of Material Engineering
E SC	419	Electronic Properties and Applications of Materials
E SC	445	Semiconductor Optoelectronic Devices
E SC	450	Synthesis and Processing of Electronic and Photonic Materials
E SC	455	Electrochemical Methods in Corrosion Science and Engineering
E SC	483	Simulation and Design of Nanostructures
E SC	484	Biologically Inspired Nanomaterials
E SC	501	Solar Cell Devices
E SC	502	Semiconductor Heterojunctions and Applications
E SC	511	Engineering Materials for Energy Conversion and Storage
E SC	536	Wave Propagation and Scattering
E SC	537	Multiple Scattering Theories and Dynamic Properties of Composite Materials
E SC	543	Laser Microprocessing
E SC	550	Power Semiconductor Devices
E SC	551	High Power Energy Storage
E SC	555	Neuroscience Data Analysis
E SC	582	Micro- and Nano-Structured Light Emitting Devices
E SC	583	Micro-and Nano Opelectronic Devices and Applications
BIOE	512	Cell and Molecular Bioengineering
BIOE	517	Biomaterials Surface Science
CHEM	448	Surface Chemistry
CHEM	543	Polymer Chemistry
MATSE	413	Solid-State Materials
MATSE	414	Mechanical Properties of Ceramics
MATSE	436	Mechanical Properties of Materials
MATSE	507	Biomaterials Surface Science
BIOE	517	Biomaterials Surface Science
Materials Cont'd: Select at least one course from the following list; each is a 3-credit course.		
MATSE	400	Crystal Chemistry
MATSE	508	Biomedical Materials
BIOE	508	Biomedical Materials
MATSE	514	Characterization of Materials
MATSE	544	Computational Materials Science of Soft Materials
MATSE	545	Mechanical Properties of Ceramics 1
MATSE	564	Deformation Mechanisms in Materials
MATSE	581	Computational Materials Science II: Continuum, Mesocale Simulations
MATSE	501	Thermodynamics of Materials
MATSE	503	Kinetics of Materials Processes
MATSE	512	Principles of Crystal Chemistry
Engineering Science: Select at least one course from the following list; each is a 3-credit course.		
E MCH	407	Computer Methods in Engineering Design
E MCH	461	Finite Elements in Engineering
E MCH	533	Scanned Image Microscopy
E MCH	552	Mechanics of the Musculoskeletal System
BIOE	552	Mechanics of the Musculoskeletal System
I E	552	Mechanics of the Musculoskeletal System

E MCH	560	Finite Element Analysis
E MCH	563	Nonlinear Finite Elements
M E	563	
E SC	400H	Electromagnetic Fields
E SC	407H	Computer Methods in Engineering Science, Honors
E SC	445	Semiconductor Optoelectronic Devices
E SC	456	Introduction to Neural Networks
E E	456	
EGEE	456	
E SC	481	Elements of Nano/Micro-electromechanical Systems Processing and Design
E SC	482	Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics
E SC	483	Simulation and Design of Nanostructures
E SC	484	Biologically Inspired Nanomaterials
E SC	501	Solid State Energy Conversion
E SC	502	Semiconductor Heterojunctions and Applications
E SC	521	Pattern Transfer at the Nanoscale
E SC	522	Fabrication and Characterization for Top-Down Manufacturing
E SC	523	Fabrication and Characterization for Bottom-up Nano-manufacturing
E SC	525	Neural Engineering: Fundamentals of Interfacing with the Brain
E SC	527	Brain Computer Interfaces
E SC	540	Laser Optics Fundamentals
E SC	541	Laser-Materials Interactions
E SC	542	Laser-Integrated Manufacturing
E SC	544	Laser Laboratory
E SC	550	Power Semiconductor Devices
E SC	551	High Power Energy Storage
E SC	577	Engineered Thin Films
E SC	581	Microelectromechanical Systems/Smart Structures
CHEM	466	Molecular Thermodynamics
E E	420	Electro-Optics: Principles and Devices
E E	422	Optical Engineering Laboratory
E E	432	RF and Microwave Engineering
E E	442	Solid State Devices
E E	522	Electro-Optics Laboratory
E E	542	Semiconductor Devices
PHYS	524	Physics of Semiconductors and Devices
PHYS	572	Laser Physics and Quantum Optics

SEMINAR: Select two seminars from the following list; each is a 1-credit course.

E MCH	514 (1 cr.)	Engineering Science & Mechanics Seminar
E SC	514 (1 cr.)	Engineering Science & Mechanics Seminar

THESIS RESEARCH: Select 6 credits from the following list; each is a variable credit course offering.

E MCH	600	Thesis Research
E MCH	610	Thesis Research Off Campus

E SC	600	Thesis Research
E SC	610	Thesis Research Off Campus

Other courses may be approved by petition.

2.3 Non-Thesis Master of Science Degree: Engineering at the Nano-scale

Practicing engineering at the nano-scale is an undertaking that builds on a foundation of engineering at the micro-scale and requires a broad background encompassing advanced safety and environmental impact knowledge, ethics awareness, broad technical depth, and interdisciplinary professional preparation. The objectives of the graduate degree program in Engineering at the Nano-scale proposed here by the Department of Engineering Science and Mechanics are to meet the educational needs of those practicing or contemplating practicing engineering at the nano-scale and to address the growing industry demand for personnel with this perspective.

Table 1: Proposed Degree Requirements

	Proposed one-year residence-based MS degree
Total number of course credits	27
Minimum number of course credits from the ESM department	15 (5 core courses)
Minimum number of 500 level course credits	21 out of 30
Colloquium credits	None
Research credits	3 (E SC 596)
Total number of credits	30

Students seeking the one-year residence-based Master of Science (M.S.) degree in Engineering at the Nano-scale will be required to start their degree in fall semester of every year and complete all the required course work and their degree by the end of the following summer.

The proposed plan of study is as follows:

- Fall semester: 12 credits of course work + 1 credit of E SC 596 Individual Study

- Spring semester: 12 credits of course work + 1 credit of E SC 596 Individual Study
- Summer semester: 3 credits of course work + 1 credit of E SC 596 Individual Study

This proposed one-year residence-based Master of Science (M.S.) degree in Engineering at the Nano-scale culminates with 3 credits of research (E SC 596) which must result in a scholarly paper that satisfies the Graduate School requirement for a culminating research experience. This culminating experience may include the student making use of the facilities of the ESM Teaching/Videoining Nanotechnology cleanroom of the ESM Center for Nanotechnology Education and Utilization (CNEU) in his or her research. The 3 credits of E SC 596 research will include at least 5 hours of responsible conduct of research (RCR) covering publication practices and responsible authorship, conflicts of interest, research misconduct, ethics, peer review, mentoring, data management, and collaborative research as specified by the Graduate School for Scholarship and *Research Integrity* (SARI) requirements.

The topic of the scholarly paper will be determined by the M.S. Nano Program Director and the student. The scholarly paper must demonstrate the student's capability to integrate and apply concepts and techniques learned in the courses and thereby demonstrate the technical, environmental, ethical, and safety knowledge needed to practice engineering at the nano-scale. An electronic copy of the approved culminating research paper must be submitted to the ESM department at least two weeks before the end of summer classes. Students who need more time to complete the final paper may extend the submission due date after the third semester (summer). The degree will be granted after the paper has been reviewed and approved, and all degree requirements have been met. Students are not required to remain in residence while they complete the final paper. Subject to permission of the author, this paper will be posted on the department web site and will be available to interested persons.

Core Courses:

The Engineering at the Nano-scale graduate program requires 5 core courses (15 credits in addition to the 3 credits of E SC 596 research experience) for this one-year residence-based Master of Science (M.S.) degree. Four of the required core courses (E SC 520, 521, 522 and 523) in the proposed program are new graduate courses and the course proposals are attached. The proposed numbers and names for the core courses are as follows:

- E SC 412 Nanotechnology: Materials, Infrastructure, and Safety
- E SC 520 Engineering at the Nano-scale
- E SC 521 Pattern Transfer at the Nano-scale
- E SC 522 Fabrication and Characterization for Top-down Nano-manufacturing
- E SC 523 Fabrication and Characterization for Bottom-up Nano-manufacturing

Summary of pre-requisites:

E SC 412: at least 7th semester standing in a science or engineering curriculum

E SC 520: none

E SC 521: none

E SC 522: E SC 412, E SC 520, E SC 521

E SC 523: E SC 412, E SC 520, E SC 521

Elective Courses:

Four 3-credit electives in the proposed program may be selected from any of the courses listed below. Additional courses may be taken, as approved by the MS “Nano” Program Director.

- E SC 414M Elements of Material Engineering
- E SC 445 Semiconductor Optoelectronic Devices
- E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials
- E SC 481 Elements of Nano/Micro-electromechanical Systems Processing and Design
- E SC 482 Micro-optoelectromechanical Systems (MOEMS) and Nanophotonics
- E SC 483 Simulation and Design of Nanostructures
- E SC 484 Biologically Inspired Nanomaterials
- BIOE 512 Cell and Molecular Bioengineering
- CHEM 511 Chemical Nanoscience
- E SC 501 Solar Cell Devices
- E SC 502 Semiconductor Heterojunctions and Applications
- E SC 511 Engineering Materials for Energy Conversion and Storage
- E SC 541 Laser-Materials Interactions
- E SC 542 Laser-Integrated Manufacturing
- E SC 550 Power Semiconductor Devices
- E SC 551 High-Power Energy Storage
- E SC 577 Engineered Thin Films
- E SC 581 Microelectromechanical Systems/Smart Structures
- E SC 582 Micro- and Nano-Structured Light Emitting Devices
- E SC 583 Micro- and Nano-Optoelectronic Devices and Applications
- E SC 584 (proposed) Introduction to Bio-Architecture
- E MCH 543 Shape Memory, Smart Materials and Mechanical Behavior (in formal review)
- E MCH 544 Multiscale Modeling and Materials (in Level 1 review)
- E MCH 545 Nanomechanics (in Level 1 review)

Research Experience:

- E SC 596 Individual Study

Table 2: Proposed Plan of Study

Fall Semester (13 credits)	
E SC 412	Core 1 (3)
E SC 520	Core 2 (3)
E SC 521	Core 3 (3)

ELECTIVE	SELECT Elective (3)
E SC 596	Individual Study (1)
Spring Semester (13 credits)	
E SC 522	Core 4 (3)
E SC 523	Core 5 (3)
ELECTIVES	SELECT Electives (6)
E SC 596	Individual Study (1)
Summer Semester (4 credit)	
E SC 596	Individual Study (1)
ELECTIVE	SELECT Elective (3)

Examples of three emphasis areas, Energy, Electronics and Photonics, and Materials, are listed in Tables 3a-3c respectively. It must be stressed that these tables are examples only. Students do not have to take these specific electives but may choose 4 different elective courses subject to the requirement that at least 2 courses must be 500-level courses and approved by the M.S. Nano Director.

The courses in the exemplary tables below are available now and are consistent with a Fall 2016 start of the program.

Table 3a: Energy Emphasis

Course Title	Description
E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials	The materials science of applying thin film coatings, etching, and bulk crystal growth; includes materials transport, accumulation, epitaxy, and defects.
E SC 501 Solar Cell Devices	Principles of photovoltaic energy conversion and their utilization in engineering devices. Emphasis on solar cell research and development efforts.
E SC 502 Semiconductor Heterojunctions and Applications	Theory, fabrication techniques, and electronic applications of semiconductor heterojunctions, including metal-semiconductor and electrolyte-semiconductor junctions.
E SC 511 Engineering Materials for Energy Conversion and Storage	This course treats engineering materials and systems employed in conventional and unconventional direct energy conversion and energy storage.
E SC 551 (M E 551) High Power Energy Storage	High-power energy storage technologies including advanced batteries, ultracapacitors, and flywheels.
E MCH 545 Nanomechanics	Study of forces and motion on synthetic and biological materials at the nanoscale using continuum mechanics theories and experimental techniques (e.g., atomic force microscopy, transmission electron microscopy, nanoindentation).
CHEM 511 Chemical Nanoscience	The fundamental chemistry of nano-particle synthesis.

Table 3b: Electronics and Photonics Emphasis

Course Title	Description
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E SC 445 Semiconductor Optoelectronic Devices	The course will present the basic engineering science and technology involved in modern semiconductor optoelectronic devices.
E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials	The materials science of applying thin film coatings, etching, and bulk crystal growth; includes materials transport, accumulation, epitaxy, and defects.
E SC 482 Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics	Introduction to the scientific principles and applications of Micro-Optoelectromechanical and Nanophotonic devices and systems. .
E SC 501 Solar Cell Devices	Principles of photovoltaic energy conversion and their utilization in engineering devices. Emphasis on solar cell research and development efforts.
E SC 502 Semiconductor Heterojunctions and Applications	Theory, fabrication techniques, and electronic applications of semiconductor heterojunctions, including metal-semiconductor and electrolyte-semiconductor junctions.
E SC 582 Micro- and Nano-Structured Light Emitting Devices	This course covers fundamental theories and cutting-edge technologies related to light emitting diodes (LED).
E SC 583 Micro- and Nano-Optoelectronic Devices and Applications	Advanced fundamental theories and cutting edge technologies related to micro and nanophotonic devices such as photodetectors, on chip nanophotonic devices, nanolasers, resonators, light confining structures, waveguides, etc.

Table 3c: Materials Emphasis

Course Title	Description
E SC 414M Elements of Material Engineering	Structure and imperfections in engineered materials; their influence on properties, behavior, and processing. Applications of metals, ceramics,

	polymers, and composites.
E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials	The materials science of applying thin film coatings, etching, and bulk crystal growth; includes materials transport, accumulation, epitaxy, and defects.
E SC 481 Elements of Nano/Micro-electromechanical Systems Processing and Design	Interdisciplinary fundamentals of scientific principles of nano/microelectromechanical systems (NEMS/ MEMS), including design, fabrication and machining of miniature systems.
E SC 483 Simulation and Design of Nanostructures	Introduction to computer simulation techniques and their applications at the physical/life sciences interface.
E SC 541 Laser-Materials Interactions	Laser beam interactions with metallic, ceramic, polymeric and biological materials; effects of wavelength, power, spatial and temporal distributions of intensity.
E SC 542 Laser-Integrated Manufacturing	Integration of lasers into manufacturing processes: laser-assisted surface modifications; laser joining; laser-based material shaping processes.
E MCH 544 Multiscale Modeling and Materials	Modeling techniques in materials, science; coupling schemes bridging traditional numerical methods at different length, time scales.
E MCH 545 Nanomechanics	Study of forces and motion on synthetic and biological materials at the nanoscale using continuum mechanics theories and experimental techniques (e.g., atomic force microscopy, transmission electron microscopy, nanoindentation).
Chem 511 Chemical Nanoscience	The fundamental chemistry of nano-particle synthesis.

2. 4-Master of Engineering in Engineering Mechanics

While this degree is based primarily on graduate lecture course work, the candidate is required to submit to the department a scholarly written report on a developmental study involving at least one area represented in the course work. A maximum of three credits of E MCH/E SC 596 can be assigned to the work performed on the M. Eng. report. The report must be comparable in its level of work and quality to a graduate thesis. Furthermore, it must also contain a nontechnical abstract in addition to the usual technical abstract.

At least two weeks prior to commencement, the graduate student shall deliver to the department office, two acceptable bound copies of his or her paper for retention by the department. In addition, an oral examination based on the student's study and course work will be administered to the candidate. Residence at University Park Campus is not required (provided the department or supervisory committee and the dean of the Graduate School agree that a complete program of study can be pursued at, for example, Penn State Harrisburg, Penn State Erie, or Penn State Great Valley).

The course requirements for the Master in Engineering in Engineering Mechanics are as follows: 31 total credits, of which 27 are 3-credit 400/500 levels classes in engineering/math/science, 3 course credits can be independent study towards the project report (E MCH/E SC 496/596), and 1 seminar (E MCH/E SC 514). Of the 27 course credits, 22 must be from this department and have an E MCH or E SC prefix; dual listed courses will count as long as one of the listings is from ESM. A maximum of 6 credits at the 400 level are

allowed for the coursework; any increase beyond the six 400-level credits must be approved by the ESM graduate officer via a petition. The seminar credit cannot be used to satisfy general course requirements. A summary of the general course requirements for the M. ENG degree is shown below in Table 2-4.

Table 2-4: Courses Credit Overview for M. Eng. Degree

1.	Total (all courses including required)	31
2.	Analysis	3 (min)
4.	Fields	3 (min)
5.	Motion	3 (min)
6.	Materials	3 (min)
7.	E MCH/E SC 514 (Seminar)	1
8.	Independent Study (E MCH/E SC 496/596)	3 (max)

Specific course requirements for the Master of Engineering in Engineering Mechanics (M ENG) are straightforward and go as follows: Beyond the 1 credit in seminar (E MCH/E SC 514), no specific courses is required. However, students are required to take at least one (1), 400/500 level course from four specific categories designated as: Analysis, Fields, Motion, and Materials. The remaining course credit requirements may be taken at the discretion of the student and their academic/report adviser provided they satisfy the requirements of Table 2-4. Table 2-5 shows the overall course and credit structure of the M ENG degree while Table 2-6 lists the courses corresponding to Analysis, Fields, Motion, and Materials. Additional courses belonging to these categories may be approved by the ESM graduate officer via a petition. Please note that the categories were selected to give students breadth and depth in the core aspects of Engineering Mechanics and encompass both 400 and 500 level courses.

Table 2-5: Required Courses Overview for M ENG Degree

Analysis	Fields	Motion	Materials	
E MCH/E SC 407	E MCH 400/500	E MCH 401	E MCH 402/506	E SC 502
E MCH 461/560	E MCH 507	E MCH 409/520	E MCH 403	E SC 540
E MCH 524A	E MCH 446/546	E MCH 412/528	E MCH 440	E SC 541
E MCH 524B	E MCH 509	E MCH 470	E MCH 530	E SC 543
E MCH 550	E MCH 516	E MCH 523	E MCH 532	E SC 544
E MCH 562	E MCH 521	E MCH 525	E SC 501	E SC 577
E MCH 563	E MCH 531	E MCH 527	E MCH 471	
E SC 404H	E MCH 540	E MCH 570	E MCH 473	
E SC 406H	E MCH 581	E MCH 571	E MCH 534	
E SC 456	E SC 400H	E SC 551	E MCH 535	
	E SC 405		E MCH 582	
	E SC 445		E SC 414M	
	E SC 536		E SC 450	
	E SC 537		E SC 455	
	E SC 540		E SC 475	
			E SC 481/581	

Table 2-6: Required Course Categories for M ENG Degree

1.	Total	31
2.	At University Park Campus	24
3.	400 courses	0 - 6
4.	500 courses	27 - 22
5.	E MCH and/or E SC (except 514 or 600)	22
6.	E MCH/E SC 514 (Seminar)	1
7.	Independent Study (E MCH 496 or 596)	3

2. 5-Time Limits for All Masters Degrees

All requirements for a master's degree comprising the M.S. and M ENG (including acceptance of a thesis, paper, or project report as may be specified), whether satisfied on the University Park campus or elsewhere, must be met within 8 years of admission to degree status. Extensions may be granted by the Graduate School in

appropriate circumstances.

2. 6-Integrated Undergraduate/Graduate Study

Integrated Undergraduate/Graduate Study (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 and senior thesis. Since up to 12 credits earned as an undergraduate may be applied to both degree programs, and the M.S. thesis is an expansion of the B.S. thesis, the time required for completion of integrated undergraduate/graduate studies is normally less than for the separate degree programs. Actual time required is determined by the individual student's objectives, needs, and diligence. In no case, however, should the acceleration of work in the major be at the expense of the richest possible undergraduate and graduate experience. Hence, there must be a balance between the accelerated specialization and a sound general education. More information on the IUG program may be found at <http://www.gradschool.psu.edu/faculty-and-staff/faculty/iugs/>.

2.6.1-IUG Application Procedures and Guidelines

1. IUG proposals may be initiated by Engineering Science students with a GPA of 3.4 or better. Time of admission to the program: Students shall be admitted to an IUG program no earlier than the beginning of the third semester of undergraduate study at Penn State (regardless of transfer or AP credits accumulated prior to enrollment) and no later than the end of the second week of the semester preceding the semester of expected conferral of the undergraduate degree, as specified in the proposed IUG plan of study. It is important to contact the ESM Graduate Officer to start the process.
2. IUG proposals may be initiated by Engineering Science students with a GPA of 3.4 or better and holding at least fifth semester standing no later than the third week of their 7th semester. It is important to contact the ESM Graduate Officer to start the process.
3. IUG applicants must complete and submit an application to the Penn State Graduate School (<http://www.gradschool.psu.edu/apply/>). The following documents should be generated before uploading them to the Graduate Admissions website.
 - a) A personal statement that summarizes the student's academic progress, outlines long-term goals, states the proposed use of IUG status, and addresses in moderate detail the research area that will constitute the focus of the graduate degree. Usually, one page is sufficient.
 - b) Three faculty recommendations including one from the academic adviser, as well as the prospective research mentor for the master's program if different. The latter must address the details of the proposed area of research focus and assess the student's ability to conclude the program. These recommendations will be uploaded to the Graduate Admissions website by the faculty. Applicants will need to contact the faculty to ask for a recommendation and then you will supply their contact information on the Reference Section of the Graduate Admissions website.
 - c) Full transcript of undergraduate courses
 - d) GRE scores are not required for Penn State undergraduate students.

4. The application for IUG status also consists of the following information. Contact the Graduate Officer for the form entitled “ IUG Supplement“ for documentation.
 - a) An explicit plan of study leading to the M.S. Degree. 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.
 - b) A financial plan. The applicant must discuss a financial plan with the prospective research mentor for the master's program must submit a financial plan for funding the applicant for the period between the conferral of the bachelor's and the master's degrees. The financial plan must address the payment of tuition and fees as well as a monthly stipend for living expenses and health insurance, in accordance with the prevailing rules of the Graduate School. Visit <http://gradsch.psu.edu/current/funding.html> for funding modes and <http://tuition.psu.edu/CostEstimate.asp> for estimated tuition and fees. The applicant may be self-funded or funded through external scholarships or through a research assistantship by the prospective research mentor. An applicant who is not offered a research assistantship, fellowship, or external scholarship will be eligible for a teaching assistantship from the ESM department, subject to availability of funds. ***When available, TA support for all IUG students is limited to a maximum of 2 semesters.*** The applicant must contact the graduate officer to discuss the financial plan after meeting with the research adviser to discuss funding options.
5. Applicants are notified by the action of the ESM Graduate Committee. When a candidate has been approved for IUG status by the Engineering Science and Mechanics Department, Schreyer Honors College (if appropriate) and the Graduate School, he or she will receive a letter of notification from the Graduate School Director of Graduate Admissions.
6. Undergraduate tuition rates will apply as long as the student is an undergraduate, unless the student receives financial support such as a research or teaching assistantship that covers the payment of graduate tuition.
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 a probationary period of a semester to meet or exceed the 3.20 GPA requirement in light of extenuating circumstances. If IUG status is terminated, the provisions of item 2(b), above, relative to 12 credits being applicable to both an undergraduate and graduate degree program, cease to apply. Termination of the IUG status would require the student to fulfill all regular requirements of the M.S. degree program in order to obtain the M.S. ESMCH degree
8. An appropriate notation of participation in the Integrated Undergraduate/Graduate Study (IUG) program will be made on the student’s transcript.

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

for the M.S. ESMCH Degree.

Chapter 3: Doctor of Philosophy in Engineering Science and Mechanics

The Ph.D. in Engineering Science and Mechanics (ESMCH) degree may be attained after completing the Engineering Science and Mechanics M.S. program (including IUG) or directly from a B.S. degree. For students holding a B.S. degree, the M.S. ESMCH guidelines already discussed must be followed along with the additional requirements outlined below.

The Ph.D. ESMCH degree is conferred in recognition of high attainment and productive scholarship. Admission to candidacy is by examination. Thereafter, the student's work is supervised by an *ad hoc* committee of the Graduate Faculty, which administers the examinations required by the department and Graduate School and reports the outcome to the Graduate School via the department. Certain departmental requirements must also be met.

While a student may be admitted to the Graduate School and the department to begin working towards a doctoral degree, the student is not a doctoral candidate until he or she has passed a candidacy examination and has been admitted to candidacy. Admission to candidacy will be based on:

- 1 The academic record of the student.
- 2 The opinion of the Graduate Faculty of the Department regarding his or her overall fitness for candidacy.
- 3 The results of a candidacy examination.

3.1-The Candidacy Examination

The Candidacy Examination **may** be taken after earning 18 credits beyond the baccalaureate degree, but **must** be taken prior to the end of the second semester in residence after 24 credits beyond the baccalaureate degree have been earned. Students entering with a master's degree must therefore take the Candidacy Examination prior to the end of their second semester in residence, not counting the summer session. All students must be registered with either full-time or part-time degree status for the semester in which the Candidacy Examination is taken.

This examination is offered twice a year, during October/November and March/April. The examination consists of two parts, a Written Component and a Research Component, both of which are administered by an Examination Board comprised of three tenure-track/tenured ESM faculty members or full-time full professors in the ESM Department. There are five Boards for each Concentration/Specialty Exam (see sections below) that are appointed at the beginning of each academic year. At the beginning of each semester (within the first few weeks) that the exam is offered, a Town Hall style meeting is scheduled so that all students considering taking the exam can meet with the Board Chairs and ask specific questions about topics, format, etc.

3.1.1 -Written Component

The Written Component of the Candidacy Exam consists of a Concentration/Specialty Exam. Each student must choose, in consultation with his/her research adviser, the Concentration area for his/her examination. A Board for each Concentration area creates the written examination, and conducts the Research (oral) Component of the Candidacy Examination (see Part II).

In order to guide student preparation, a detailed list of courses and texts indicative of the scope and level of questions on all exams is made public by each Board in the Town Hall style meetings at the beginning of every semester. Graduate students are strongly advised to attend these meetings, even if considering the exam in a future semester.

3.1.2-The Concentration/Specialty Exam (3 hours)

Students must choose to be examined in one of the following five areas: **Mechanics, Materials, Electromagnetism, Bionanotechnology, or Neural Engineering Science**. A representative list of topics is included below with each category. In general, questions on the Concentration Exams are at the level of upper-level undergraduate and introductory graduate courses.

The broad coverage of each Concentration Exam is intended to provide an evaluation of the fundamental knowledge required for advanced study in the student's chosen field of Engineering Science and Mechanics. However, exams may be structured to give students some choice in the questions that must be adequately answered in order to pass, based on the emphasis of a specific number of subspecialties within each concentration area. The minimum passing requirements will be clearly spelled out by each Examination Board at the beginning of each semester.

Mechanics: This exam may include the following subject areas: advanced mechanics of materials; elementary continuum mechanics and elasticity; advanced dynamics, linear vibrations and wave propagation; and applied mathematics (this includes: partial and ordinary differential equations, linear algebra, complex variables, numerical methods, calculus of variations, and advanced calculus). Questions may be qualitative and/or quantitative.

Materials: The exam assesses the student's general knowledge of metallic, semiconductor, ceramic, and polymer materials, and their properties in relation to engineering device applications. The focus is on concepts gleaned and retained from undergraduate courses in chemistry, physics, materials, mechanics and devices. Questions may be qualitative as well as quantitative, and deal with behavior of materials; their growth, characterization and processing; response to load and/or environment; and synthesis into useful structures. Basic expertise in quantitative analysis and design of engineering devices is also evaluated.

Electromagnetism: The exam assesses the student's general knowledge in the following areas: electrostatics; time-varying electromagnetic fields and Maxwell's equations; plane-wave propagation in different linear materials and across boundaries; electric circuits and elementary circuit analysis; wave-particle duality of electromagnetic radiation and interaction with matter, photons; blackbody radiation, Compton and photoelectric effects; absorption, skin depth and plasma frequencies in metals, polarization of dielectrics; complex conductivity; magnetization and magnetic domains; masers and lasers; geometrical and physical optics. Questions may be qualitative and/or quantitative.

Bionanotechnology: The exam is concerned with the fundamental physics of nanostructures at the physical/life science interface. The student should understand the fundamental laws of molecular materials, apply the principles of thermodynamics and statistical mechanics to bio and nano materials, be aware of the imaging and spectroscopic methods that are commonly used in bionanotechnology and explain the fundamentals of device applications. Questions may be qualitative and/or quantitative.

Neural Engineering Science: This exam assesses the student's fundamental knowledge of the nervous system, the basic principles of engineering sciences for probing, interacting, and modeling the nervous system.

Any student taking the exam should be able to demonstrate knowledge of the basic anatomical structure of the nervous systems, the biophysics of excitable membranes, the origin of neuronal action potentials, principles of electrical measurement and stimulation of the nervous system, and the materials science required for such interfaces. In addition, the student should know basic signal processing of continuous and discrete signals including spectral and correlation analysis. Questions may be qualitative and/or quantitative.

3.1.3 Research Component (Oral Exam)

The second part of the Candidacy Exam consists of a research proposal and an oral presentation on an “Emerging Technology.” Topics are intended to be examples of new or anticipated interdisciplinary areas of research that extend beyond the borders of any one field of study and will not be on or closely related to the student’s thesis topic. As such, the Chair of each Concentration/Specialty Examination Board, in consultation with the members of their Board, compiles a list of acceptable topics every semester. The list is provided to the ESM Graduate Officer who then allocates topics to the students two weeks before the written examination. As already mentioned, these topics will be considerably different from the Ph.D. research topics of the students.

It should be noted and understood that the proposal and presentation are NOT to be survey reports that only list current trends and/or the results of others. While your work may include such items, they must be properly cited. The proposal must be a plan for tackling a specific research problem and/or solving a particular issue or enigma.

Moreover, the proposal must be the students’ own work and cannot include help from others (adviser, friends, family, student’s etc.) in terms of the writing, editing, figures etc. It is acceptable to ask experts specific questions as long they are not involved in reviewing your writing, work, and/or ideas.

If the student does seek assistance from others, does not properly cite all referenced works, and/or copies texts or figures without citation, this is plagiarism and the student will fail this portion of the exam!

Each research proposal should be a short paper no greater than 5 pages in length. While a certain degree of specificity is expected, the research proposal should summarize the main research questions in the chosen emerging technology area and discuss how the student might tackle the question that has been posed by the Examination Board. Each student is expected to develop their proposal from the perspective of their own disciplinary concentration, and should discuss how the ideas and methodologies of their concentration impact, and contribute to the development of, the emerging technology area. The student is also asked to discuss the limitations of their own discipline in addressing the needs of the emerging field, and discuss possible interfacing with other disciplines actively pursued in the ESM Department.

The research proposal paper is intended to be an assessment of the student’s creativity as well as their communication via written English. This document must be given in triplicate (hard copies) to the Board no more than 2 weeks after the completion of Part I of the exam. It must be accompanied by a signed statement as follows: “The student certifies that this document is entirely his/her own work, and it conforms entirely to the ESM Academic Integrity Policy currently in force.” The ESM Academic Integrity Policy is provided in Section XIV (page 41) of this handbook.

The oral presentation and examination are scheduled within one week of submitting the proposal. The student is expected to give a short (approximately 15 minutes) presentation on their chosen emerging technology area, and then is examined on their proposal as well as on Part I (Written Component) of the

Candidacy Exam, as deemed necessary and appropriate by the Examination Board. The oral presentation and examination do not generally exceed 90 minutes in duration, and can be much shorter. Remedial coursework to attain proficiency in English may be prescribed.

The student's research adviser is invited to join the Examination Board as a non-voting member. If the adviser is already a member of the Examination Board, he/she is not permitted to vote, and another ESM graduate faculty member is asked, temporarily, to act as a voting member.

3.1.4-Other Administrative Details

During the second week of every semester, all of the Examination Boards jointly conduct an open Town Hall style meeting to advise doctoral students on the scope of the Candidacy Examination for its concentration/ specialty and to answer questions on the nature of the forthcoming examination. Every student is strongly encouraged to speak to the Board of his/her chosen area, in preparation for the examination.

The Board evaluates student performance on each portion of the Candidacy Exam, and makes a recommendation to pass or fail to the entire ESM Graduate Faculty, which makes the final decisions. The Board may also recommend, and the faculty ultimately require, that a student take certain additional courses including remedial education to improve English competency, regardless of the outcome of the exam.

A student who does not pass the Candidacy Examination on the first attempt may be permitted by the ESM Graduate Faculty to retake the examination, in its entirety and without a change of track, the next time it is offered. Failing twice will result in the student being asked to graduate with a master's degree (if all requirements for that degree are met by the student) rather than the doctoral degree.

Within six weeks after passing the Candidacy Examination, the student is required to set up the Doctoral Committee.

3. 2-The Doctoral Committee

The Doctoral Committee is appointed by the dean of the Graduate School (upon recommendation of the graduate officer and with the cognizance of the thesis adviser) and is responsible for overseeing the candidate's program and for administering the oral comprehensive and the final oral examination. When the student is notified that he or she is to be recommended for candidacy, the candidate should form their doctoral committee within six weeks. General guidance of a doctoral candidate is the responsibility of a doctoral committee consisting of four or more active members of the Graduate Faculty, which includes at least two faculty members in the major field. The dissertation adviser must be a member of the doctoral committee. The dissertation adviser usually serves as chair, but this is not required. If the candidate is also pursuing a dual-title field of study, a co-chair representing the dual-title field must be appointed. In most cases, the same individual (e.g., dissertation adviser) is a member of the Graduate Faculty in both the major and dual-title fields, and in such cases may serve as sole chair.

At least one regular member of the doctoral committee must represent a field outside the candidate's major field of study in order to provide a broader range of disciplinary perspectives and expertise. This committee member is referred to as the "Outside Field Member." In cases where the candidate is also pursuing a dual-title field of study, the dual-title representative to the committee may serve as the Outside Field Member.

Additionally, in order to avoid potential conflicts of interest, the primary appointment of at least one regular member of the doctoral committee must be in an administrative unit that is outside the unit in which the dissertation adviser's primary appointment is held (i.e., the adviser's administrative home; in the case of tenure-line faculty, this is the individual's tenure home). This committee member is referred to as the "Outside Unit Member." In the case of co-advisers, the Outside Unit Member must be from outside the administrative home(s) of both co-advisers. The committee co-chair can also serve as the Outside Unit Member. In some cases, an individual may have a primary appointment outside the administrative home of the student's dissertation adviser and also represent a field outside the student's major field of study; in such cases, the same individual may serve as both the Outside Field Member and the Outside Unit Member.

If the candidate has a minor, that field must be represented on the committee by a "Minor Field Member. A person who is not a member of the Graduate Faculty (and may not be affiliated with Penn State) who is otherwise qualified and has particular expertise in the candidate's research area may be added as a "Special Member," upon recommendation by the head of the program and approval of the dean of the Graduate School (via the Office of Graduate Enrollment Services). A Special Member is expected to participate fully in the functions of the doctoral committee. If the Special Member is asked only to read and approve the doctoral dissertation, that person is designated a Special Signatory. Occasionally, Special Signatories may be drawn from within the Penn State faculty in particular situations.

A faculty member from Engineering Science and Mechanics can now serve as the outside unit member provided their area of expertise is significantly different from those of the other committee members. The chair or one of two co-chairs must be in the Engineering Science and Mechanics major and is normally the faculty member who has agreed to supervise the thesis research.

Each candidate should then prepare to meet with their doctoral committee to review past and future course work in relation to the proposed field of research; the first meeting will normally be called within one month of the formation of the committee. Thereafter, the candidate should be ready to discuss their work from time to time and prepare written reports in advance of the meetings when called upon to do so. In particular, a written proposal of the intended thesis research will be required in advance of the oral part of the comprehensive examination. The committee will meet with the candidate at least once between the comprehensive and final oral examination to review progress. All meetings will be called by the chair of the doctoral committee.

3. 3-Course Requirements

The candidate's doctoral committee plays a major role in determining course requirements regarding the quantity and subject matter. However, certain minimum requirements are specified by the departmental graduate faculty depending on whether they are starting from a BS or MS degree as follows:

1. As stated in Section 2, the course requirements for the Master of Science degree in Engineering Science and Mechanics include a total of 24 course credits which must include 12 credits in the major (E MCH or E SC). The graduate faculty may from time to time announce groupings of courses recommended for the purpose of meeting this requirement.
2. Students may enter the Ph. D program after completing an M.S. degree or directly from the B.S. degree. The student must have completed an appropriate baccalaureate or master's degree prior to admission. In addition: 1) at least 18 graduate credits must be earned in 400- and 500- level lecture/laboratory courses approved by the department; and 2) 3 credits of a graduate seminar (E MCH 514 or E SC 514) must be earned beyond the master's degree requirements. Only two 400 level courses may be taken for

these 18 credits. If starting from a B.S. program, a total of four 400 level (3-credit each) courses may be taken.

3. Nine credits taken during each fall and spring semester (for students on half-time assistantships) should consist of lecture or laboratory course work until the student has met the residency requirements (see section 3.5) of the Graduate School and has passed the comprehensive examination. Audits, project courses (e.g., E MCH/E SC 496, 590, and 596) and courses in the 600 series do not count toward this requirement.
4. Those students who select a minor field of study must consult the department responsible for that field to determine requirements. A minor consists of no fewer than 15 additional credits.
5. A minimum of 3 credits of E MCH/E SC 514 must be taken. This requirement can **NOT** be used to satisfy item (2) above. This requirement is in addition to the seminar credit requirements for the Master of Science degree. Students enrolled in the Ph.D. program starting from a B.S. program must satisfy the seminar credit requirements of the M.S. degree in addition to the 3-credit requirement for the Ph.D. degree for a total of 5 credits of 514.
6. Ph.D. students are permitted a maximum of 12 credits of letter grades for Thesis Research, E MCH/ E SC 600. These 12 credits additional to the 6 credits of letter grades for the M.S. degree.
7. A student pursuing the Ph.D. degree program directly from a B S degree (hence, no M.S. degree) must satisfy **ALL** the coursework, seminar and thesis research credits for the M.S. degree, in addition to the requirements for the Ph.D.. However, while a M.S. degree and thesis are not required, they are strongly recommended.

3. 4-English Competence

A candidate for the degree of Doctor of Philosophy is required to demonstrate a high level of competence in the use of the English language, including reading, writing, listening, and speaking. Remedial course work will be prescribed, if necessary.

3. 5-Academic Status and Residency Requirements

There is no required minimum number of semesters of study. However, over a twelve-month period, covering the interval between admission and the completion of the Ph.D. program, the candidate must spend at least two semesters as a registered full-time student engaged in academic work on the University Park Campus. Summers do not count toward this requirement.

1. A student can be at most, a half-time graduate assistant to be classified as a full-time student during a semester. A semester in which a student is a three-quarter-time graduate assistant cannot be counted toward residency requirements. Note: regulations prohibit international students from being three-quarter time.
2. A student is not permitted to register for E SC 601, E MCH 601, E SC 611 or E MCH 611 (no credit thesis preparation) until after residency requirements are satisfied and the comprehensive examination is passed.

3. International students are required by the Immigration and Naturalization Service (INS) to maintain normal progress. Those who are enrolled in less than full-time status during the fall or spring semesters must ask their adviser to notify, in writing, the University Office of Global Programs (previous name: International Students) for their INS record.
4. Students who are earning both an M.S. and a Ph.D. at Penn State are allowed 6 (M.S.) plus 12 (Ph.D.) research credits for a total of 18 research credits with a quality (letter) grade for thesis research (E MCH 600 or E SC 600). All remaining credits will be graded as R (Research).
5. A full-time student (fall and spring) is defined as follows depending on their employment status (Graduate Assistant or GA):
 - a. No employment—15 to 18 credits
 - b. One-quarter time GA—9 to 14 credits
 - c. One-half time GA—9 to 12 credits
6. Teaching Assistants are expected to register for 10 credits of graduate coursework. Permission must be granted from the ESM graduate officer for more or less credits. *Note: all students hired as Teaching Assistants (TA) are REQUIRED to be on campus and ready to begin working on the date specified on their signed contract. For Fall semesters, the start date is typically 1 week before the start of classes. Failure to be on campus at this date is grounds to have the TA contract and all support terminated.*

3.6-The Comprehensive Examination

1. The candidate must have completed at least 18 credits of courses (approved by the chair of the doctoral committee or the Ph.D. graduate adviser), not including the seminar and thesis research credits, beyond the M.S. degree course requirement, before taking the comprehensive examination.
2. The comprehensive examination can be oral, written, or both; it will be designed and given by the student's doctoral committee and scheduled by the Graduate School. The subject areas are broad and may cover any area related to the student's doctoral thesis.
3. The Graduate School requires a minimum of **two (2) weeks'** notification and hence, the candidate must notify the Graduate School and ESM officer of the date, time, and place of the comprehensive examination at least two and one-half weeks before the examination. The paperwork required to initiate this is in the ESM main office. Failure to have this done in the required time-frame may cause the exam to be delayed until the following semester.
4. The candidate must deliver to the doctoral committee a well-documented thesis research proposal, including a critical literature survey, scope, and objectives of the thesis research and approach at least **two (2) weeks** before the comprehensive examination. This proposal must be approved in writing by the thesis adviser prior to delivering it to the committee members.
5. Candidates are required to have a minimum grade point average of 3.00 for work done at the University at the time the comprehensive examination is given.

6. The student must be registered as a full or part-time degree student for the semester in which the comprehensive examination is taken.

3. 7-The Final Oral Examination

The final oral examination for both M.S. and Ph.D. degrees are open to the public. While the examination is primarily related mainly to the thesis, it may cover the candidate's whole field of study without regard to courses that have been taken either at Penn State or elsewhere.

Normally, the examination may not be scheduled until the semester after the comprehensive examination was passed. However, the dean of the Graduate School may grant a waiver in the case of an outstanding student. The thesis presentation should emulate the presentation of a paper at a technical session of a national professional meeting as follows:

1. It should be presented within a definite time period—roughly 30-45 minutes for a Ph.D.
2. The talk should have been rehearsed with the actual visual aids prior to the presentation in order that the time limitations can be verified.
3. A good rule-of-thumb is 1-2 minutes per slide.
4. The presentation should proceed without interruption from the audience.
5. All questions to the examinee must be answered by the examinee.

It is important to note that an excessively long presentation may result in rejection by the committee. Additionally, examinees should be able to address the novel contributions of their research, its strengths, the challenges that were addressed, and future research directions.

When the candidate delivers the draft of the thesis to each member of their doctoral committee, a determination of the dates available for the final oral examination should be made and (with the concurrence of the chair) a request should be filed with the department's graduate officer for transmittal to the dean of the Graduate School of the examination date. Forms for this are in the main ESM office. The transmittal date must be a minimum of two and one-half weeks after delivery of the thesis. ***No exceptions are permissible.*** Students are responsible for having drafts of their theses pre-checked by the Graduate School's Thesis Office by the deadline specified by the Graduate School. This will allow the student to be cleared for graduation and to remain on the graduation list. The student must be registered with full or part-time status for the semester the thesis examination is scheduled.

The department's graduate officer will determine whether all of the requirements for the degree have been met before a request for a final oral examination is forwarded to the Graduate School.

A favorable vote of at least two-thirds of the members of the committee is required for passing the examination. In the case of failure, it is the responsibility of the doctoral committee to determine whether the candidate may take another examination.

After the examination, it shall be the responsibility of the thesis adviser to determine whether the candidate has responded appropriately to the suggestions of the committee members in regard to the thesis.

3. 8-The Thesis

The thesis must represent a significant contribution to the field of study and be presented in a scholarly manner. It must also reveal an ability on the part of the candidate to do independent research of high quality and demonstrate considerable experience in using a variety of research techniques.

Each thesis must contain a nontechnical abstract as the last appendix to explain the contributions reported in the thesis in terms that members of the general public may understand.

A completed thesis must be delivered to the Graduate School prior to the commencement when the candidate expects to receive the degree, per the deadline specified by the Graduate School.

Moreover, the completed thesis must incorporate any changes decided upon at the final oral examination. It must be accompanied by two separate copies of an abstract.

Prior to commencement, the student shall deliver to the department office two acceptable copies of his/her thesis (one copy for the department file and the other for the adviser), bound in accordance with the requirements as detailed in the Graduate School's Thesis Guide. The Thesis Guide may be found at: <http://forms.gradsch.psu.edu/thesis/thesisdissertationguide2012.pdf>. Copies may be purchased at the Thesis Office, 211 Kern Building. Costs incurred with thesis binding are the responsibility of the student.

Reminder: The department head must sign the signatory page prior to binding.

3. 9-Time Limitation

A doctoral student is required to complete the program including acceptance of the doctoral thesis within eight years from the date of acceptance as a candidate.

Extensions may be granted by the dean of the Graduate School in appropriate circumstances.

When a period of more than six years has elapsed between the passing of the comprehensive examination and the completion of the program, the student is required to pass a second comprehensive examination before the final oral examination will be scheduled.

3. 10-Continuous Registration Requirement

It is expected that all graduate students will be properly registered at a credit level appropriate to their degree of activity (see I-3 Registration.). After a Ph.D. candidate has passed the comprehensive examination and met the two semester full-time residence requirement, the student must register continuously for each fall and spring semester (beginning with the first semester after both of the above requirements have been met) until the Ph.D. thesis is accepted and approved by the doctoral committee. Note that students who are in residence during summers must also register for sessions.

If the final oral examination or comprehensive examination is held during summer, registration is required.

Post-comprehensive Ph.D. students can maintain registration by registering for credits in the usual way or by registering for noncredit E SC or E MCH 601 or 611, depending upon whether they are devoting full time or part time to thesis preparation. Students are permitted to register for E SC or E MCH 590 (colloquium), E SC or E MCH 602 (supervised experience in college teaching), and audits along with E SC/E MCH 601. Students who want to combine course work with thesis preparation must register for E SC or

E MCH 600 or 611 (i.e., not for 601, which is full-time thesis preparation). Note that the least expensive way for a post comprehensive exam Ph.D. student to work full time on research and thesis preparation is to register for E SC or E MCH 601. This is the procedure of choice for international students who need to maintain status as full-time students for visa purposes.

If a Ph.D. student will not be in residence for an extended period for compelling reasons, the graduate dean will consider a petition for a waiver of the continuous registration requirement. The petition must come from the doctoral committee chair and carry the endorsement of the department or program chair. This option offers a substantial savings in tuition. International students are still subject to INS (Immigration and Naturalization Service) rules regarding their student status.

ESM Ph.D. Program Quick Reference

1. Admission to grad program. Begin working (courses) toward Ph.D. Program
2. Candidacy Exam • given twice yearly (November and April; first week)
3. Thesis committee selection and appointment • notify graduate staff assistant of committee selection • Graduate Staff Assistant notifies Graduate Officer of committee selection • minimum of four members of graduate faculty, of whom three must be from ESM faculty, and a minimum of one from the graduate faculty of a related field • student registers for E MCH/E SC 600 series thesis research credits prior to completing the comprehensive exam
4. Meet with doctoral committee within one month of formation
5. Preparation of research objectives
6. Fulfillment of course requirements
7. Residency requirement • nine (9) credits minimum; 596 and 600 not allowable
8. Comprehensive exam • eighteen (18) credits beyond the M.S. requirement-check with Ph.D. adviser for approval. Student notifies Graduate Staff Assistant, in writing, who in turn notifies the Graduate School. Graduate School requires two (2) weeks' notice • student supplies committee members (2 weeks prior) with well documented research proposal. Communications and English competency requirement must be met prior scheduling comprehensive exam. • After oral comprehensive exam student may register for E MCH/E SC 601.
9. Continuous registration • must register continuously each semester (excluding summers) beginning with the semester following the passing of comprehensive examination and continuing each semester until final oral examination is passed. Must register the semester of the candidacy, comprehensive and final oral examinations - even if taken during summer session
10. Final oral exam (thesis defense) • notify Graduate Staff Assistant who in turn notifies Graduate School • date must be at least **two (2) weeks** after delivery of thesis to thesis committee • seven (7) weeks before degree conferral • three or more months must have elapsed between the passing of comprehensive examination and scheduling of the final oral examination
11. Deliver thesis electronically to Graduate School plus two bound copies of thesis to department two weeks prior to Commencement. Every thesis must contain a nontechnical abstract in addition to the usual technical abstract.
12. Time limitation • all requirements including submission of the thesis must be completed within eight years' of candidacy date . The student must schedule a meeting with the ESM Graduate Officer every semester to determine if program requirements are being met. The student must also communicate with the Research Adviser at least biweekly.

Chapter 4: Joint M.D. /Ph.D. in Engineering Science and Mechanics Degree Program

4.1-Joint M.D./Ph.D. in Engineering Science and Mechanics Degree Program (M.D./Ph.D. ESMCH)

The Engineering Science and Mechanics (ESM) Department and the College of Medicine (COM) offer a joint degree program in which a student can receive an M.D. degree from the College of Medicine and a Ph.D. degree in Engineering Science and Mechanics from the College of Engineering (M.D./Ph.D. ESMCH). The Joint M.D./Ph.D. ESMCH Degree Program forms the basis for an interdisciplinary, transformational program dedicated to educating a new generation of *Physician Engineering Scientists*, working at the frontiers of clinical and translational research.

Students in the Joint M.D./Ph.D. in Engineering Science and Mechanics degree program will complete 4 years of medical studies (designated years M1 through M4) in the Medical School, College of Medicine, and 3 or more years of Graduate Study (designated years G1 through G3 or GX) in the Engineering Science and Mechanics (ESM) Department.

After successful completion of the first 2 years of medical school, including all required rotations and Step 1 of the United States Medical Licensing Examination (USMLE), the candidate will apply for admission to the Ph.D. program in Engineering Science and Mechanics.

Students will complete all requirements for the Ph.D. Degree in Engineering Science and Mechanics, including SARI (Scholarship and Research Integrity) training for the Responsible Conduct of Research (RCR) that must be met by students admitted to the program with either a baccalaureate or a master's degree, with the following exceptions: students admitted to the program with a baccalaureate degree will be allowed to double count 14 professional credits (24% of the total graduate credits) toward graduate course credit for the Ph.D. ESMCH degree; and, students admitted to the program with a master's degree will be allowed to double count 7 professional credits (21% of the total graduate credits) toward graduate course credit for the Ph.D. ESMCH degree.

A minimum grade-point average of 3.00 for work done at the University after admission is required for doctoral candidacy, admission to the Comprehensive Examination, the Final Oral Examination, and for graduation. *It should be noted that passage of the Final Oral Examination is necessary, but it is not sufficient for award of the degree as the dissertation must also be accepted as the ultimate step.*

Students will complete all requirements for the M.D. degree that must be met by students admitted to the program with either a baccalaureate or master's degree, with the following exceptions: baccalaureate degree holders will be allowed to double count 10 research credits (E SC/E MCH 600/610) toward professional credits for the M.D. degree; and, master's degree holders will be allowed to double count 5 research credits (E SC/E MCH 600/610) applied to the Ph.D. ESMCH degree toward professional credits for the M.D. degree.

Students may take the Candidacy Examination after completing 18 credits of approved graduate course work. Master's degree holders accepted into the Joint M.D./Ph.D. ESMCH degree program may take the Candidacy Examination in the Spring semester of Year G1, but no later than the Fall Semester of G2. Baccalaureate degree holders accepted into the Joint M.D./Ph.D. ESMCH degree program may take the

Candidacy Examination within 3 semesters of entry into the Ph.D. program (expected to be the Fall Semester of G2).

Upon successfully completing the Candidacy Examination, students should appoint their doctoral committee as discussed in Chapter 3, Section 3.2.

The Comprehensive Examination may be taken in a semester following the Candidacy Examination, and must be completed at least one semester prior to submission of the dissertation.

Students must prepare and submit a scholarly dissertation that demonstrates comprehensive and in-depth knowledge of a topic in Engineering Science and Mechanics. The contents and conclusions of the dissertation must be defended at the time of the Final Oral Examination. The scholarly research should be suitable for submission for publication in a refereed journal as approved by the student's adviser(s). Normally, the Final Oral Examination may not be scheduled until at least three months after the Comprehensive Examination.

Following completion of the Ph.D. dissertation, students will return to medical school to complete Years M3 and M4 of the professional M.D. degree.

4.2- Current Requirements for the Ph.D. Degree in Engineering Science and Mechanics (Ph.D. ESMCH)

As detailed in Chapter 3, candidates for the Ph.D. degree in Engineering Science and Mechanics typically take a minimum of 59 total credits beyond the baccalaureate degree (42 graduate course credits, 5 seminar credits, and typically 12 research credits). Master's holders typically take 33 credits (18 graduate course credits, 3 seminar credits, and up to 12 research credits). Exceptions to these requirements may be approved by petition.

Students may enter the Ph.D. program after completing an appropriate baccalaureate or master's degree prior to admission. At least 18 graduate credits must be earned in 400- and 500-level lecture/laboratory courses approved by the department and 3 credits of a graduate seminar (E MCH 514 or E SC 514) must be earned beyond the master's degree requirements. Students must demonstrate English proficiency, pass a Candidacy Examination, a Comprehensive Examination, as well as a Final Oral Examination. A doctoral dissertation on an appropriate topic is required. It must be a well-organized account of research undertaken by the student and show initiative and originality. A minimum grade-point average of 3.00 for work done at the University is required for doctoral candidacy, admission to the Comprehensive Examination, the Final Oral Examination, and for graduation. It should be noted that passage of the Final Oral Examination is necessary but it is not sufficient for award of the degree; the dissertation must be accepted, as the ultimate step. Please refer to Chapter 3 for more details.

4.3- Current College of Medicine Graduation Requirements

The current Medical School graduation requirements are described below:

1. Satisfactory completion of all Year 1 required courses.
2. Completion of the Year 1 Objective Structured Clinical Examination (OSCE).
3. Satisfactory completion of all Year 2 required courses.
4. Completion of the Year 2 OSCE.

5. Satisfactory completion of all Year 3 required clerkships, 3 Island courses, and 1 required elective month.
6. Satisfactory completion of the Year 3 choice procedures by the end of Year 3.
7. Passing score on the Year 3 OSCE.
8. Completion of the Medical Student Performance Evaluation (MSPE); a requirement for residency application.
9. Satisfactory completion of all Year 4 required acting internships, Neurology clerkship, Year 4 Island, the Humanities requirement, and 4 electives.
10. Passing score on the United States Medical Licensing Examination (USMLE) Step 1.
11. Passing score on USMLE Step 2 Clinical Knowledge.
12. Passing score on USMLE Step 2 Clinical Skills.
13. Completion of the Medical Student Research (MSR) Project.
14. Observed History and Physical Examination:
 - Completed during the acting internship or the electives taken during the 4th year of medical school.
 - Complete 2 examinations that must be signed off by an attending physician, chief resident or a fellow.

4.4- Joint Program Requirements

The Joint M.D./Ph.D. in Engineering Science and Mechanics Degree Program will require 4 years of medical study (Years M1 through M4) and 3 or more years of graduate study (Years G1 through G3 or GX) in Engineering Science and Mechanics fields. While there will be some level of double-counting of courses, the candidates will fulfill the full requirements of both programs as detailed below.

4.4.1- Overview of Program Requirements for the Joint M.D./Ph.D. ESMCH Degree

Program-specific requirements for the Joint M.D./Ph.D. in Engineering Science and Mechanics are listed below:

- Students must demonstrate English proficiency, pass a Candidacy Examination, a Comprehensive Examination, and a Final Oral Examination.
- Students may enter the Joint M.D. /Ph.D. program with an approved baccalaureate or master's degree.
- Students must successfully complete the first and second year of the M.D. curriculum (Years M1 and M2) and Step 1 of the United States Medical Licensing Examination (USMLE) before applying for admission to the graduate program in Engineering Science and Mechanics.
- Baccalaureate degree holders may double count 14 professional credits (equivalent to 24% of the total graduate credits) approved by the ESM Graduate Faculty toward graduate course credit for the Ph.D. ESMCH degree.
- Master's degree holders may double count 7 professional credits (equivalent to 21% of the total graduate credits) approved by the ESM Graduate Faculty toward graduate course credit for the Ph.D. ESMCH degree.
- In the summer between Years M1 and M2, students may complete a laboratory rotation in Engineering Science and Mechanics and apply 3 graduate credits toward the Ph.D. ESMCH degree.
- Students will undertake graduate studies in Engineering Science and Mechanics in Years G1 through GX.

- For baccalaureate degree holders, graduate study in the summer between Years M1 and M2 and in Years G1-GX will require 31 credits of graduate course work, 2 credits of seminar, and 12 credits of thesis research (E SC/E MCH 600/610). The selected course work must comply with the requirements for the M.S. and Ph.D. degrees in Engineering Science and Mechanics.
- Each student's program will be customized according to research interests and approved by the research adviser and ESM Graduate Officer.
- For master's degree holders, graduate study in the summer between Years M1 and M2 and in Years G1-GX will require a minimum of 18 credits of graduate course work to satisfy the requirements for the Ph.D. degree in Engineering Science and Mechanics, 2 credits of seminar, and 6 credits of thesis research (E SC/E MCH 600/610). Each student's program will be customized according to research interests and approved by the research adviser and ESM Graduate Officer.
- Students will complete 5 hours of required SARI (Scholarship and Research Integrity) training for the Responsible Conduct of Research (RCR) through the E SC/E MCH 514 Seminar series and via special workshops, as opportunities arise.
At least 3 seminars/workshops will be offered each fall; 2 seminars/workshops each spring will be devoted to discussion-based RCR education via the E SC/E MCH 514 seminar class, special workshops, guest speakers, and/or example/case study followed by directed RCR discussions.
- Students may take the Candidacy Examination after completing 18 credits of approved graduate course work.
- Master's degree holders accepted into the Joint M.D./Ph.D. program may take the Candidacy Examination in the Spring Semester of Year G1, but no later than the Fall Semester of G2.
- Baccalaureate degree holders accepted into the Joint M.D./Ph.D. program may take the Candidacy Examination within 3 semesters of entry into the Ph.D. program (expected to be the Fall Semester of G2).
- Upon successfully completing the Candidacy Examination, students should appoint their doctoral committee.
- Students are expected to focus on research following completion of all course work.
- For baccalaureate degree holders, 10 research credits (E SC/E MCH 600/610) applied toward the Ph.D. ESMCH degree will be double counted toward the professional M.D. degree.
- For master's holders, 5 research credits (E SC/E MCH 600/610) applied toward the Ph.D. ESMCH degree will be double counted toward the professional M.D. degree.
- Students may take the Comprehensive Examination in a semester following the Candidacy Examination. The Comprehensive Examination must be completed at least one semester prior to submission of the Ph.D. dissertation.
- Students must prepare and submit a scholarly dissertation that demonstrates comprehensive and in-depth knowledge of a topic in Engineering Science and Mechanics. The contents and conclusions of the dissertation must be defended at the time of the Final Oral Examination. The scholarly research should be suitable for submission for publication in a refereed journal as approved by the student's adviser(s). Normally, the Final Oral Examination may not be scheduled until at least three months after the Comprehensive Examination.
- Following completion of the Ph.D. dissertation, students will return to medical school to complete Years M3 and M4 of the professional M.D. degree.

4.4.2- Professional/Graduate Credits (M.D.) For **baccalaureate** degree holders, the ESM Department will accept (double count) 14 credits of professional medical course work (24% of the total credits) appropriate to the student's research focus toward the Ph.D. degree in Engineering Science and Mechanics (Ph.D. ESMCH) as shown in **Table 4-1**. For example: 7 professional credits of MBMP 711 (*Cellular and Molecular Basis of Medical Practice*) and 7 credits of CMBMP 712 (*Cellular and Molecular Basis of Medical Practice*, a continuation of CMBMP 711) may be accepted for a total of 14 credits.

In Table 4.1 the professional credits to be double counted by ESM are highlighted in green and the graduate credits to be double counted by the College of Medicine are highlighted in yellow.

Table 4-1: Joint M.D./Ph.D. ESMCH - Engineering Baccalaureate Degree Holders

Year	Fall Semester	Spring Semester	Credits	
M1	MD Curriculum (25 professional credits)	MD Curriculum (26 professional credits)	14	Professional
	Professional Course (dual graduate credits: 7)	Professional Course (dual graduate credits: 7)		
Summer	E SC/E MCH 596 or E SC /E MCH 600 Laboratory Rotation (3 graduate credits)		3	Graduate
M2	MD Curriculum (32.5 professional + 2 graduate credits)	MD Curriculum (33 professional + 2 graduate credits)		
G1	ESM Approved Graduate Courses (9 credits)	ESM Approved Graduate Courses (9 credits)	18	Graduate
	E SC 514 or E MCH 514 Seminar (1 credit)	E SC 514 or E MCH 514 Seminar (1 credit)	2	Seminar
G2	ESM Approved Graduate Courses (10 credits)	E SC/E MCH 600/610 Research (9 credits)	10	Graduate
			9	Research
G3-GX	E SC/E MCH 600/610 Research (3 credits)	E SC 601 Thesis Preparation (0 credit)	3	Research
M3	MD Curriculum (~36 credits)	MD Curriculum (~36 credits)		
M4	MD Elective Credits (~10 credits)	MD Elective Credits (~11 credits)		
	10 credits E SC/E MCH 600/610 from G2 and G3 (dual professional credits)		59	Total

For **baccalaureate** degree holders, the College of Medicine’s Medical Curriculum Oversight Committee for Years 3 and 4 (CUMED III/IV) will accept (double count) 10 credits of E MCH 600 or E SC 600 (Thesis Research) or E MCH 610 or E SC 610 (Thesis Research Off Campus) in lieu of two 5-credit medical research electives in Year M4 of the professional M.D. curriculum.

Table 4-2: Joint M.D/Ph.D. ESMCH – Entering Master’s Degree Holders

Year	Fall Semester	Spring Semester	Credits	
M1	MD Curriculum (25 professional credits)	MD Curriculum (33 professional credits)	7	Professional
	Professional Course (dual graduate credits: 7)			
Summer	E SC/E MCH 596 or E SC/E MCH 600 Laboratory Rotation (3 credits)		3	Graduate
M2	MD Curriculum (34.5 professional credits)	MD Curriculum (35 professional credits)		
G1	ESM Approved Graduate Courses (9 credits)	ESM Approved Graduate Courses (6 credits)	15	Graduate
	E SC 514 or E MCH 514 Seminar (1 credit)	E SC 514 or E MCH 514 Seminar (1 credit)		
G2	E SC/E MCH 600/610 Research (6 credits)	E SC 601 Thesis Preparation (0 credit)	6	Research
G3-GX	E SC 601 Thesis Preparation (0 credit)	E SC 601 Thesis Preparation (0 credit)		
M3	MD Curriculum (~36 credits)	MD Curriculum (~36 credits)		
M4	MD Elective Credits (~10 credits)	MD Elective Credits (~11 credits)	33	Total
	5 credits E SC/E MCH 600/610 from G2 (dual professional credits)			

For **Master’s** degree holders, the College of Medicine’s Medical Curriculum Oversight Committee for Years 3 and 4 (CUMED III/IV) will accept (double count) 5 credits of E MCH 600 or E SC 600 (Thesis Research) or E MCH 610 or E SC 610 (Thesis Research Off Campus) applied toward the Ph.D. ESMCH degree in lieu of one 5-credit medical research elective in Year M4 of the professional M.D. curriculum. Note: the six research credits (E MCH/E SC 600/610) used to satisfy the requirements for the M.S. ESMCH cannot be used toward the M.D. degree).

Students may take the Candidacy Examination after successful completion of 18 credits of approved graduate course work. Master’s degree holders accepted into the Joint M.D./Ph.D., ESMCH program may take the Candidacy Examination in the Spring Semester of Year G1 and no later than the Fall Semester of G2. Baccalaureate degree holders accepted into the Joint M.D./Ph.D., ESMCH program may take the Candidacy Examination before the end of the third semester of entry into the Ph.D. program, expected to be the Fall Semester of G2.

For **master’s** degree holders, the ESM Department will accept (double count) 7 credits of professional medical course work (22% of the total graduate credits) toward the Ph.D. degree in Engineering Science and Mechanics (Ph.D., ESMCH) as shown in **Table 4-2**.

4.5- Admission Process and Requirements

All students must process an application via the American Medical College Application Service and be accepted for admission by the M.D./Ph.D. admissions committee in the College of Medicine. It is anticipated that the ESM Department Head, or designee, will serve on the M.D./Ph.D.

Admissions Committee, and the ESM Graduate Officer, or designee, will serve on the M.D./Ph.D. Steering Committee. Admission to the program requires a minimum GPA of 3.5 and a Medical College Admission Test (MCAT) score of 32. Exceptions to the minimum requirements may be made for students with special backgrounds, abilities, and interests. Applicants will be accepted up to the number of places available for new students. Students must successfully complete Years M1 and M2 and Step 1 of the United States Medical Licensing Examination (USMLE) before entering the graduate degree program. All requirements for the Ph.D. degree must be completed prior to Year M3 of medical studies.

Students must apply to the Graduate School for admission to the graduate program after successful completion of the first 2 years of medical school, including all required rotations, and Step 1 of the United States Medical Licensing Examination (USMLE). For admission to the Graduate School, an applicant must hold either (1) a bachelor's degree from a U.S. regionally accredited institution or (2) a postsecondary degree that is equivalent to a U.S. baccalaureate degree earned from an officially recognized degree-granting international institution. International applicants must hold the equivalent of an American four-year baccalaureate degree. Graduates in engineering, the mathematical sciences, mathematics, engineering science, and materials science and engineering who present a 3.5 grade-point average will be considered for admission. Exceptions to the minimum 3.5 grade-point average may be made for students with special backgrounds, abilities, and interests. Applicants will be accepted up to the number of places available for new students.

Scores from the Graduate Record Examination (GRE) are required for admission. At the discretion of the Graduate Officer, a student may be granted provisional admission pending receipt of acceptable GRE scores.

International applicants must take and submit scores for the TOEFL (Test of English as a Foreign Language) or IELTS (International English Language Testing System). The minimum composite score for the IELTS is 6.5. The minimum score accepted for the internet-based test (iBT) is 80 (total), with a 19 on the speaking section. Applicants with an iBT speaking score between 15 and 18 may be considered for provisional admission, which requires an institutional test of English proficiency and, if necessary, remedial course work.

International applicants who have received a baccalaureate or a graduate degree from a college/university/institution in the following countries are exempt from the TOEFL/IELTS requirement: Australia, Belize, British Caribbean and British West Indies, Canada (except Quebec), England, Guyana, Republic of Ireland, Liberia, New Zealand, Northern Ireland, Scotland, the United States, and Wales.

All program-specific documents for admission (e.g., transcripts, letters of recommendation, etc.) must be submitted by all applicants.

Chapter 5: Engineering Mechanics as a Minor

M.S. degree students outside the Engineering Science and Mechanics department wishing to minor in Engineering Mechanics are expected to take 9 credits of 500-series lecture courses in Engineering Mechanics. *A member of the ESM faculty **MUST** serve on the student's thesis committee.*

Students desiring a minor must have their major program notify the Graduate Programs Office, via the Department of Engineering Science and Mechanics, of their intent to complete a specific minor. The department will verify that the minor requirements have been met at the time the student graduates. Completion of the minor is recorded on the student's transcript.

For Ph.D. students, the minor must consist of no fewer than 15 credits including those applied toward a master's degree and must meet the approval of the Engineering Science and Mechanics graduate faculty. Students are required to take at least 12 credits of E MCH 500-series lecture courses, not including E MCH 514 and E MCH 596, and will be examined on this course work during the comprehensive exam by the faculty representing the Engineering Mechanics minor. Completion of the minor will appear on the student's transcript.

Chapter 6: Concurrent Graduate Degree Candidacies

Occasionally a candidate for an advanced degree in one major field may desire to begin work on either a master's or a doctoral degree in a second field before completing the first program. In this event the student will consult with both graduate program heads and, under their direction, draw up a program of study to meet the requirements of the two degrees. Any common agreements, such as the required completion of one program before advancing beyond a specified point in the other, should be added to the stated program of study as part of the agreement before it is approved, signed by the representatives of each degree, and sent to the Office of Graduate Programs for review. The Office of Graduate Programs will verify that degree requirements in both programs will be met by the proposed plan of study and that overlap between the programs is not excessive.

Additional concerns such as credit requirements, examining procedures, project/paper or thesis content and conferral of degrees is available from the graduate officer.

Chapter 7: Graduate Assistantships

The graduate assistantship (Research Assistantship {RA} or Teaching Assistantship {TA}) is a vehicle for providing a stipend to help meet living and other incidental expenses during graduate study. In exchange for this stipend (and also the remission of tuition fees) the student is expected to assist in the teaching and/or research programs of the department. For the purposes of codification, this effort is assessed using a forty hour week as a nominal “full-time” effort, so that a “half-time” assistantship (the usual arrangement) implies a commitment to an average of twenty hours per week of effort for the entire semester (eighteen weeks).

Note: all students hired as Teaching Assistants (TA) are REQUIRED to be on campus and ready to begin working on the date specified on their signed contract. For Fall semesters, the start date is one week before classes start. Failure to be on campus at this date is grounds to have the TA contract and all support terminated.

It is in the best interests of the student and the department that the student progress to graduation in a timely fashion. Under normal circumstances, an M.S. student should achieve the requisite credits as a half-time graduate assistant in three semesters (2 for IUG students); a Ph.D. student should achieve all required credits beyond the M.S. degree in six semesters.

Although very rare, summer session of support is roughly equivalent to two-thirds of a semester.

In order to conserve the resources of the University, College, and Department, all requests for graduate assistantships beyond these time limits will be closely examined for evidence of satisfactory progress, even if a student is funded as a Research Assistant (RA).

In the event an individual has reached or exceeded these limits (whether or not the funding was for a research assistantship or for a teaching assistantship or some combination thereof), the department will not provide teaching assistantship funding except in the most unusual situations. As such, students being supported on assistantships should plan accordingly.

Outside Employment—A student holding any fellowship, graduate assistantship or scholarship may not normally accept employment of any kind beyond that specified by his or her appointment. International students may not seek outside employment under any circumstances unless approved by the INS.

Academic Load—Graduate assistantships are awarded to enrolled Penn State graduate students. The Graduate School regulates both the maximum and the minimum number of course credits a graduate student may take according to the schedule in **Table 7-1**.

Students must satisfy the minimum course requirement to retain their assistantship and are strongly encouraged to carry maximum credits.

International students must carry a full-time load.

Further explanations of Graduate School policies can be found in the Penn State Graduate Degree Programs Bulletin <http://bulletins.psu.edu/bulletins/whitebook/index.cfm>.

Table 7-1: Graduate Assistantship

Graduate Assistantship	Employment Hours per Week	Credits to be Taken Fall/Spring Semesters*	Credits to be Taken Summer Sessions
	None	15-18	5-12
¼ time	10	9-14	5-7
½ time	20	9-12	4-6
¾ time	30	6-8	3-5

*Courses taken for audit do not count toward the minimum credit load but do count toward the maximum credit load.

Periods of Appointment—Appointments cover eighteen (18) weeks each academic semester. Start and termination dates may be varied by agreement between the student and the Graduate Officer, in collaboration with the student’s adviser. In the absence of a specific agreement to the contrary, the period of appointment is 20 weeks ending on commencement day, or an equivalent date, of the semester in question.

Payments—Payments are made on the last working day of the month. Unsatisfactory performance of graduate assistantship duties will result in a summary suspension of payments.

Note: all students hired as Teaching Assistants (TA) are REQUIRED to be on campus and ready to begin working on the date specified on their signed contract. For Fall semesters, the start date is one week before classes start. Failure to be on campus at this date is grounds to have the Teaching Assistantship (TA) contract and all support terminated.

Office/Desk Assignments—Office/desk assignments for research assistants are made by the supervising faculty member. Assignments for teaching assistants are made by the department head on a semester by semester basis. Students need to confirm their assignments at the beginning of each semester.

Electronic Employment Bulletin Board

It is advisable for all students to visit Penn State’s Career Services in person at the Bank of America Career Services Center located on the corner of Bigler and Eisenhower Road or on-line at <http://studentaffairs.psu.edu/career/>.

Chapter 8: Teaching Assistant Responsibilities

A Teaching Assistant (TA) in the Department of Engineering Science and Mechanics may be assigned any (or a combination) of the following assignments:

- Classroom recitation
- Classroom laboratory leadership
- Homework and test grading
- Tutoring
- Office hours to assist students

Teaching assistants are supervised by a faculty member who assigns specific duties, mentors the teaching assistant throughout the semester, and supervises the teaching assistant's performance. Teaching assistants are also required to participate in an instructional development program (ENGR 888 with details to be provided prior to the semester in which the teaching assistant is assigned teaching responsibilities) as established by the University and the College of Engineering.

All international teaching assistants are required to take and pass an oral proficiency test (AEOCPT). A modified version of the oral language SPEAK test is administered through Penn State's Center for English as a Second Language, 305 Sparks Building. Students must be preregistered for the exam and may do so by calling the center at 865-7365. This may be done upon the student's arrival at Penn State. It is the center's policy to give the test only once. If a student wishes to take the test a second time, he or she may take it through the Educational Testing Services (see below for address).

Note: The Test of Spoken English (TSE), if available, may be taken in a student's home country.

Applications for the TSE may be obtained from:

Educational Testing Services (ETS)

Box 899
Princeton, NJ 08541

Results should be forwarded to:

The Center for English as a Second Language

305 Sparks Building
University Park, PA 16802

New Teaching Assistants are required to attend an orientation meeting, to be determined by the course coordinator, at the beginning of the Fall semester. New graders have a separate orientation meeting. Every new TA, with tasks other than grading, must take ENGR 888 in the first semester.

Chapter 9: Changing Programs

Students who decide that their academic and research interests would be better met under the auspices of a program other than those offered through the Engineering Science and Mechanics department, are first encouraged to discuss their intentions with their academic adviser and the graduate officer. In the event a change of program is the best course of action, students must request a major change by processing a Change of Major Form through the Graduate Programs Office in 114 Kern Graduate Building. This request to change programs will then be forwarded to the chairs (or advisers) of both the prospective program and the current program. The chairs (or advisers) of both programs will review the proposed change prior to making a final decision.

Chapter 10: Health Insurance

Penn State requires medical insurance for all graduate assistants, for all international students, and for all dependents of international students. Please visit the websites of the Student Insurance Office for more information.

1. <http://studentaffairs.psu.edu/health/services/insurance/>
2. <http://studentaffairs.psu.edu/health/services/insurance/graduate.shtml>

Chapter 11: International Students

Immigration and Naturalization Service (INS) continually updates its rules and regulations. An international student must remain in compliance with all INS regulations at all times. It is the student's responsibility to be aware of the student's obligation. Information can be found at University Office of Global Programs (formerly: Office of International Programs) web site: <http://global.psu.edu/>.

All incoming International Students (TA, RA or self-supported) are required to take the AEOCPT (American English Oral Communication Proficiency Test) administered by the Department of Linguistics, the first semester they are in residence. If the student does not pass the test with a score above 250, then they are required to take an English as a Second language (ESL) course based on their AEOCPT score as outlined below:

250-300	None.	Student may assume teaching duties with no restrictions.
230-249	Enroll in ESL 118G before assuming teaching duties. <i>Students enrolled in <u>ESL 118G</u> must pass the course with a grade of "A" and pass the qualifying exit examination, called the Interactive Performance Test (IPT), before they can assume teaching duties with no restrictions.</i>	
200-229	Enroll in ESL 117G . Will require at least two semesters before student is recommended to teach. <i>Students enrolled in <u>ESL 117G</u> must receive a grade of "A" before they will be allowed to enroll in <u>ESL 118G</u>.</i>	
below 200	Enroll in ESL 115G Will require at least three semesters before student is recommended to teach. <i>Students enrolled in <u>ESL 115G</u> must receive a grade of "A" before they will be allowed to enroll in <u>ESL 117G</u>. Then must receive a grade of "A" in <u>ESL 117G</u> before they will be allowed to enroll in <u>ESL 118G</u>.</i>	

If you will be a RA or are self-supported and receive a score lower than 250 on the AEOCPT or you are admitted under a provisional status (your TOEFL does not meet the minimum Graduate School requirement), you will be required to take English as a Second language (ESL) 114G, the FIRST semester you are in residence. The AEOCPT test is scheduled for August and January. When the schedule has been announced, you will be contacted by the department to schedule. Depending on your score, you may be required to take additional English coursework.

For more information about the AEOCPT test, please visit
http://aplmg.la.psu.edu/academicPrograms/ita_sampleAEOCPTtest.shtml

****Note: The Candidacy Examination includes additional evaluation of language proficiency by ESM faculty. A student's language proficiency (written and spoken) must be considered proficient to pass the examination.****

Chapter 12: Student Organizations

Opportunities for students to participate in social, student government, and professional organizations abound. Within the department, the student branches of SES (Society of Engineering Science) and SAMPE (Society for the Advancement of Materials and Process Engineering) are active. SES is especially interested in interdisciplinary endeavors.

SAMPE has been formed for the purpose of advancing and disseminating scientific, engineering, and technical knowledge, particularly with respect to the manufacturing and processing of materials. Announcements regarding SES and SAMPE's guest speakers and other activities are routinely distributed to Engineering Science and Mechanics students.

The ESM Graduate Council elects its officers annually. The Council advises the Head of the ESM department on issues affecting graduate students and their studies. From 2005, it also organizes ESM Today, an annual research symposium for ESM students.

Student concerns and issues may be addressed through the departmental student representative(s) of the Graduate Student Association or Engineering Graduate Student Council. The Engineering Graduate Student Council actively participates in the annual College of Engineering Open House which is open to high school students and their families.

Chapter 13: Sources of Information

Selected sources of information for graduate students include:

- 1 The Graduate Degree Programs Bulletin
<http://bulletins.psu.edu/bulletins/whitebook/index.cfm>
- 2 Graduate School Thesis Guide <http://www.gradsch.psu.edu/current/thesis.html>
- 3 Schedule of Classes <http://schedule.psu.edu/>
- 4 Graduate Student Association <http://www.gradsch.psu.edu/current/gsa.html>
- 5 International Ministries <http://www.impsu.org/>
- 6 Guide to Graduate Life (published by the Graduate Student Association)
<http://www.pennstategsa.com/guide-to-graduate-life.html>
- 7 International Hospitality Council and the International Student Council (for international students)
<http://www.global.psu.edu/students/involvement.cfm>

APPENDIX A: Department Faculty

The Graduate Faculty

Opportunities for graduate studies are available in interdisciplinary and multidisciplinary research areas including: biomechanics; composite materials; continuum mechanics; electrical, magnetic, electromagnetic, optical, thermal, and mechanical properties of thin films.; experimental mechanics; lithography; microelectromechanical systems (MEMS) and micro-opto-electromechanical systems (MOEMS); micromechanics; molecular beam epitaxy; numerical methods; photovoltaic materials and devices; nanotechnology and nanobiotechnology; properties of materials; shock, vibration acoustics and nonlinear dynamics; structural health monitoring; structural mechanics; wave-material interactions; non-destructive evaluation and testing; and failure analysis. More information on specific research topics may be found under the faculty section of the ESM webpage

Engineering Science & Mechanics Faculty

- **Dinesh K. Agrawal**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Director, Microwave Processing and Engineering Center; Professor of Engineering Science and Materials
- **S. Ashok**, Ph.D. (RENSSELAER POLYTECHNIC INSTITUTE), Professor of Engineering Science
- **Osama Osman Awadelkarim**, Ph.D. (UNIVERSITY OF READING), Professor of Engineering Science and Mechanics
- **Charles E. Bakis**, Ph.D. (VIRGINIA POLYTECHNIC INSTITUTE), Distinguished Professor of Engineering Science and Mechanics
- **Long-Qing Chen**, Ph.D. (MIT), Professor of Materials Science and Engineering
- **Huanyu (Larry) Cheng**, Ph.D. (NORTHWESTERN UNIVERSITY), Assistant Professor of Engineering Science and Mechanics
- **Stephen M. Copley**, Ph.D. (UNIVERSITY OF CALIFORNIA, BERKELEY), Professor of Engineering Science and Mechanics and Senior Scientist, Applied Research Laboratory
- **Francesco Costanzo**, Ph.D. (TEXAS A & M UNIVERSITY), Professor of Engineering Science and Mechanics
- **Joseph Cusumano**, Ph.D. (CORNELL UNIVERSITY), Professor of Engineering Science and Mechanics
- **Saptarshi Das**, Ph.D. (PURDUE UNIVERSITY) Assistant Professor of Engineering Science and Mechanics
- **Melik Demirel**, Ph.D. (CARNEGIE-MELLON UNIVERSITY), Assistant Professor of Engineering Science and Mechanics, and Bioengineering
- **Cheng Dong**, Ph.D. (COLUMBIA UNIVERSITY), Distinguished Professor of Bioengineering, Engineering Science and Mechanics
- **Corina S. Drapaca**, Ph.D. (UNIVERSITY OF WATERLOO), Assistant Professor of Engineering Science and Mechanics
- **Patrick J. Drew**, Ph.D. (BRANDEIS UNIVERSITY), Assistant Professor of Neural Engineering
- **Timothy J. Eden**, Ph.D. (PENN STATE UNIVERSITY), Senior Research Associate, Applied

Research Laboratory, and Associate Professor of Engineering Science and Mechanics.

- **Renata S. Engel**, Ph.D. (UNIVERSITY OF SOUTH FLORIDA), Associate Dean for Academic Programs, College of Engineering; Professor of Engineering Design, and Engineering Science and Mechanics
- **Stephen J. Fonash**, Ph.D. (UNIVERSITY OF PENNSYLVANIA), Bayard D. Kunkle Chair and Professor Emeritus of Engineering Sciences
- **Bruce J. Gluckman**, Ph.D. (UNIVERSITY OF PENNSYLVANIA), Associate Professor of Engineering Science and Mechanics
- **Venkatraman Gopalan**, Ph.D. (CORNELL UNIVERSITY), Professor of Materials Science and Engineering, and Engineering Science and Mechanics
- **Gary L. Gray**, Ph.D. (UNIVERSITY OF WISCONSIN-MADISON), Associate Professor of Engineering Science and Mechanics
- **Reginald F. Hamilton**, Ph.D. (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), Assistant Professor of Engineering Science and Mechanics
- **M. Amanul Haque**, Ph.D. (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), Professor of Mechanical Engineering
- **Robert E. Harbaugh**, M.D. (PENNSYLVANIA STATE UNIVERSITY), Chair, Department of Neurosurgery; Professor of Engineering Science and Mechanics
- **S. I. Hayek**, Ph.D. (COLUMBIA UNIVERSITY IN CITY OF NEW YORK), Distinguished Professor Emeritus of Engineering Mechanics
- **Donald F. Heaney Jr.**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Director, Center for Innovative Sintered Products; Associate Professor of Engineering Science and Mechanics
- **Mark W. Horn**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Associate Professor of Engineering Science and Mechanics
- **Jun (Tony) Huang**, Ph.D. (UNIVERSITY OF CALIFORNIA, LOS ANGELES), Professor of Engineering Sciences and Mechanics
- **Kevin L. Koudela**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Head, Composite Materials Division, Applied Research Lab
- **Akhlesh Lakhtakia**, Sc.D. (BANARAS HINDU UNIVERSITY), Charles Godfrey Binder Professor of Engineering Science and Mechanics
- **Michael T. Lanagan**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Associate Director of the Materials Research Institute; Professor of Engineering Science and Mechanics, and Materials Science and Engineering
- **Patrick M. Lenahan**, Ph.D. (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), Distinguished Professor of Engineering Science and Mechanics
- **Herbert H. Lipowsky**, Ph.D. (UNIVERSITY OF CALIFORNIA, SAN DIEGO), Professor of Bioengineering
- **Clifford J. Lissenden III**, Ph.D. (UNIVERSITY OF VIRGINIA), Professor of Engineering Science and Mechanics
- **Maria M. Lopez de Murphy**, Ph.D. (UNIVERSITY OF MICHIGAN AT ANN ARBOR), Professor
- **Christine B. Masters**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Associate Professor of Engineering Science and Mechanics
- **R. P. McNitt**, Ph.D. (PURDUE UNIVERSITY), Professor Emeritus of Engineering Science

and Mechanics; Department Head Emeritus

- **Scott T. Miller**, Ph.D. (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), Graduate faculty Engineering Science and Mechanics
- **Wook Jun Nam**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Assistant Professor of Engineering Science and Mechanics
- **Ibrahim T. Ozbolat**, Ph.D. (UNIVERSITY AT BUFFALO, THE STATE UNIVERSITY OF NEW YORK), Associate Professor of Engineering Science and Mechanics
- **Robert N. Pangborn**, Ph.D. (RUTGERS, STATE UNIVERSITY OF NEW JERSEY), Vice President and Dean for Undergraduate Education; Professor of Engineering Mechanics
- **Jonathan S. Pitt**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Research Associate, Applied Research Laboratory, and Assistant Professor of Engineering Science and Mechanics.
- **Andrew Pytel**, (PENNSYLVANIA STATE UNIVERSITY) Professor Emeritus of Engineering Mechanics
- **Jean Landa Pytel**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Assistant Dean Emerita, College of Engineering; Associate Professor of Engineering Mechanics
- **Ramakrishnan Rajagopalan**, Ph.D. (UNIVERSITY OF CINCINNATI), Assistant Professor, Department of Engineering, Penn State Dubois, and Assistant Professor of Engineering Science and Mechanics
- **Edward W. Reutzel**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Research Associate, Applied Research Laboratory, and Assistant Professor of Engineering Science and Mechanics.
- **Joseph L. Rose**, Ph.D. (DREXEL UNIVERSITY), Paul Morrow Professor of Engineering Science and Mechanics in Design and Manufacturing
- **Nicholas J. Salamon**, Ph.D. Professor of Engineering Mechanics
- **Steven J Schiff**, Ph.D., M.D. (DUKE UNIVERSITY), Brush Chair Professor Engineering; Professor of Neurosurgery and Engineering Science and Mechanics; Director, Center for Neural Engineering
- **Albert E. Segall**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Professor of Engineering Science and Mechanics
- **Barbara A. Shaw**, Ph.D. (JOHNS HOPKINS UNIVERSITY), Professor of Engineering Science and Mechanics
- **Elzbieta Sikora**, Ph.D. (POLISH ACADEMY OF SCIENCES), Research Associate
- **Ivica Smid**, Ph.D. (UNIVERSITY OF VIENNA), Associate Professor of Engineering Science and Mechanics
- **Samia A. Suliman**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Assistant Professor of Engineering Science and Mechanics
- **Bernhard R. Tittmann**, Ph.D. (UNIVERSITY OF CALIFORNIA, LOS ANGELES), Schell Professor of Engineering Science and Mechanics
- **Judith A. Todd**, Ph.D. (CAMBRIDGE UNIVERSITY), Department Head, P.B. Breneman Chair and Professor of Engineering Science and Mechanics
- **Mirna Urquidi-Macdonald**, Ph.D. (UNIVERSITE PARIS SUD (PARIS XI)), Professor Emerita of Engineering Science and Mechanics
- **Douglas E. Wolfe**, Ph.D. (PENNSYLVANIA STATE UNIVERSITY), Senior Research Associate, Applied Research Laboratory, and Associate Professor of Engineering Science and Mechanics and Associate Professor of Materials Science and Engineering

- **Jian Xu**, Ph.D. (UNIVERSITY OF MICHIGAN AT ANN ARBOR), Assistant Professor of Engineering Science and Mechanics
- **Qing X. Yang**, Ph.D. (GEORGIA INSTITUTE OF TECHNOLOGY), Professor of Radiology
- **Sulin Zhang**, Ph.D. (UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN), Associate Professor of Engineering Science and Mechanics

APPENDIX B: Engineering Mechanics and Engineering Science Courses Qualifying for Graduate Credit

The most up-to-date list of Engineering Science and Mechanics Courses may be found at

<http://bulletins.psu.edu/graduate/courses/>

Note: In addition to the following graduate (500-level) credit courses, upper class Engineering Science and upper class Engineering Mechanics courses (with the exception of E SC 433H) may be selected for inclusion in the student's graduate program. Please consult **sections 2-2; 2-4; and 3-3** for additional information. Selections shall be made in accordance with your adviser's guidance. Upper class (400-level) Engineering Science and Engineering Mechanics courses can be found at:

<http://bulletins.psu.edu/undergrad/>.

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