



**PennState**  
College of Engineering

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# Engineering Science and Mechanics

## Graduate Programs Guide

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## 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:

<https://www.engr.psu.edu/faculty-staff/academic-integrity.aspx>

## ESM Inclusion Statement

### **Making Inclusive Research and Learning Environment a High-Quality Academic Experience for All Students**

#### **[Expectations for cultivating an inclusive environment.]**

*We, ESM department, are creating an environment promoting inclusion and diversity, consistent with expectations of STEM professionals. We are supporting the feeling of belonging for all participants. Each of us (students/staff/faculty) can make a deliberate effort to...*

- participate in supporting inclusive exchanges amongst all participants in class, lab, group meetings;
- avoid any inappropriate actions or statements based on individual characteristics (such as age, religion, race, ethnicity, sexual orientation, gender identity, gender expression, marital status, nationality, political affiliation, ability status, educational background, or any other characteristic); and
- act in accordance with academic integrity while discouraging disruptive or harassing behavior (including, but not limited to, inappropriate or intimidating behavior and language, unwelcome jokes or comments, unwanted attention, offensive images, photography without permission, real or implied threat of harm).

## Safer People Safer Places Network

Our department supports the Penn State Safer People Safer Places Network, and we are committed to creating and maintaining an open, safe, and inclusive environment honoring gender and sexual diversity. We can help you connect with resources on campus to address problems you may face that interfere with your academic and social success on campus as it relates to issues surrounding sexual and gender diversity.

For more information visit the Penn State Center for Sexual and Gender Diversity in LL011 HUB-Robeson Center or at: <https://studentaffairs.psu.edu/csgd>

# Chapter 1: General Information

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

### Master of Engineering

Engineering Mechanics (M. ENG./EMCH)

### Master of Science

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

Engineering Science and Mechanics (M.S./ESMCH) Non-Thesis Track

Engineering at the Nano-scale

### Doctor of Philosophy

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

### 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 and lasers; non-destructive evaluation and testing; wear and tribology; and forensic failure analysis. More information on specific research topics may be found under the faculty section of the ESM webpage (<https://www.esm.psu.edu/departments/faculty-list.aspx>).

## 1.1 - Programs

Programs leading to M.ENG., M.S., 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, environmental degradation of materials, shock, vibration, acoustics and nonlinear dynamics; structural mechanics; wave/materials interactions; non-destructive evaluation; microfluidics; wear and tribology; neurosurgery, neuroscience and failure analysis.

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.



A student working for a Master of Science of Engineering Science and Mechanics may pursue either a thesis or a non-thesis track. 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 thesis track is required to submit a thesis to the University. A candidate for the Master of Science degree non-thesis track is required to submit a scholarly paper to the Department of Engineering Science and Mechanics.

For the Master of Science of Engineering at the Nanoscale, a minimum of 30 graduate credits (including 3 credits of research) is required. A candidate for the Master of Science of Engineering at the Nanoscale is required to submit a scholarly paper to the Department of Engineering Science and Mechanics.

The Ph.D. ESMCH degree is conferred in recognition of high attainment and productive scholarship. Students may enter the Ph.D. program after completing an M.S. degree or directly from the B.S. degree.

The minimum number of course credits required for students entering the PhD program with a baccalaureate degree is 27 course credits in 400- and 500- level lecture/laboratory courses approved by the department, 5 credits in a graduate seminar (E MCH/E SC 514), and 12 research credits.

Students entering with M.S. degree take 18 graduate course credits, 3 credits of seminar and a minimum of 6 and up to 12 research credits.

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 qualifying examination has been passed and candidacy admission has been granted. The qualifying examination must be taken for the first time within two semesters of residency after completing a M.S. degree or 24 credits if starting with a B.S. degree.

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.

Newly developed 3-credit course, ESC 515 Research Practices in Engineering is highly recommended as it will fulfil mandatory SARI requirements (see section 1.6) and is useful for gaining the research skills required for graduate studies.

## **1.2 - 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](http://guru.psu.edu/policies/OHR/hr99.html) 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 (see <http://gradschool.psu.edu/current-students/transfer-credits/>). 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 must 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 scores are not required for admission.
4. The language of instruction at Penn State is English. English proficiency test scores (TOEFL/IELTS) are required for international applicants - 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>

### 1.3 - 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 two weeks [of the notice](#).

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 qualifying 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).***

## **1.4 - Registration**

Continuous registration is required for all graduate students except for summers unless coursework, comprehensive exam, and/or a thesis defense is scheduled for the summer semester (so you need to be registered for it).

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 students do not need to maintain full-time status, they 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."

## **1.5 - 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 qualifying, comprehensive, and final oral examinations. Graduate programs may add additional benchmarks.

## **1.6 - 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 the following:*

## **SARI (Scholarship and Research Integrity) Requirements**

The SARI program has two main components:

1. **Online Training:** You need to complete an online course on Responsible Conduct of Research (RCR) provided by CITI (Collaborative Institutional Training Initiative). Once completed, a printable certificate will be available that must be shown to the ESM Graduate Programs Assistant to verify completion.

and

2. **Discussion-based Education (total at least 5 hours):** You need to take part in a minimum of 5 hours of in-person, discussion-based educational activities that address topics related to the Responsible Conduct of Research (RCR) before graduation. This is a one-time requirement that does not need to be fulfilled each year.

In our department you can fulfil this requirement by participating in ethics seminars and discussions which are part of EMCH/ESC 514 or ESC 515 courses.

**Fulfilling your SARI requirement at PSU is the responsibility of each graduate student and failing to do so will prevent you from being able to graduate on time.**

For schedule your online training and more information, please check:

<https://www.research.psu.edu/training/sari>

*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.*

## **1.7 - 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](http://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.

Report all unsafe conditions, practices, or equipment to the supervisor, instructor or safety officer whenever deficiencies are observed.

Inform the supervisor or instructor immediately of all work-related injuries or accidents and obtain prompt medical attention when necessary.

8. 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.



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

The Department of Engineering Science and Mechanics offers a number of degree programs including: Master of Science of Engineering Science and Mechanics (MS ESMCH) thesis track, Master of Science of Engineering Science and Mechanics (MS ESMCH) non-thesis track, Master of Engineering in Mechanics (ME EMCH) and Master of Science in Engineering at the Nano-scale. The Integrated Undergraduate Graduate (IUG) program has the same requirements as the Master of Science of Engineering Science and Mechanics (MS ESMCH) thesis track.

*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 thesis and non-thesis MS ESMCH tracks is shown in Table 2.1. The Master of Science Degree (M.S.) in Engineering Science and Mechanics thesis track 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 non-thesis 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 non-thesis 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.

#### 2.1.1 - MS ESMCH Thesis Track

The thesis 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 two years 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 notify Tammy Coval so it can be entered into LionPath milestones. The student has 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 date.*** The thesis adviser has to complete the Communications Rubric for Masters Degrees and return the completed document to Tammy Coval.

A master's candidate is not required to register for the final semester in order to graduate or 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 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.

The unbound thesis must be submitted electronically via ETDs <http://www.etd.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.

The M.S. thesis track requires 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 (EMCH/ESC 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.

### 2.1.2 - MS ESMCH Non-Thesis Track

The 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 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.

Before starting or during the first week of the fall semester, non-thesis M.S. students should investigate faculty research activities within the ESM department and contact faculty they are interested in working with so selection and discussion of the student's research project can begin as soon as possible. The scholarly 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 semester 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 by their thesis adviser and Graduate Officer, 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.

## 2.2 - MS ESMCH Course Requirements for Thesis and Non-Thesis Tracks

**Specific course requirements (see also Table 2.1) for thesis and non-thesis tracks in the Master of Science degree in Engineering Science and Mechanics (MS ESMCH) are listed below; *It is the responsibility of the student and their adviser to make sure all of these requirements are met.***

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. ***Failure to take courses from these categories may require additional coursework and delays in graduation. It is the responsibility of the student and their adviser to make sure these requirements are met.***
3. 2 seminars (E MCH/E SC 514)

4. 6 Thesis Research (600 level) credits are required for the Thesis Track. 3 Independent Study (ESC or E MCH 596) credits are required for the Non-Thesis Track
5. 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.
6. 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.

**Table 2-1: Degree Requirements**

	<b>M.S. thesis Track</b>	<b>M.S. Non-Thesis Track</b>
<b>Total number of course credits</b>	24	27
<b>Recommended number of semesters</b>	4 (2 fall and 2 spring)	3 (fall, spring, summer)
<b>Minimum number of E SC/E MCH credits</b>	12 Including E MCH 524A	15 Including E MCH 524A
<b>Maximum number of credits at 400 level</b>	6	6
<b>Core courses required</b>	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
<b>Graduate seminar (E SC/E MCH 514)</b>	2	2
<b>Research credits towards M.S. degree</b>	E SC/E MCH 600 6 credits <sup>1</sup>	E SC/E MCH 596 3 credits
<b>Culminating experience</b>	Completion of research thesis and oral defense	Completion of a written scholarly paper and presentation
<b>Total credits</b>	32	32

<sup>1</sup> M.S. students are allowed a maximum of 6 credits of letter grades for 600 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.

**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.

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

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

<b>Mechanics: Select at least one course from the following list</b>		
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	Micromechanics 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	544	Multiscale Modeling of Materials
E MCH	560	Finite Element Analysis

E MCH	571	Foundation of Structural Dynamics and Vibration
AERSP	571	
M E	571	
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	552	Mechanics of the Musculoskeletal System
I E	552	
BIOE	553	Engineering of Human Work
I E	553	
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	508	Foundations of Fluid Mechanics
AERSP	518	Dynamics and Control of Aerospace Vehicles
AERSP	550	Astrodynamics
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	473	Composites Processing
AERSP	473	
E MCH	506	Experimental Stress Analysis
E MCH	530	Mechanical Behavior of Materials
E MCH	534	Micromechanics of Fracture
E MCH	535	Deformation Mechanisms in Materials
E MCH	544	Multiscale Modeling of 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	475	Particulate Materials Processing
E SC	482	
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	503	Low Dimensional Nanoelectronics
E SC	511	Engineering Materials for Energy Conversion and Storage
E SC	518	Bioprinting
E SC	536	Wave Propagation and Scattering
E SC	537	Multiple Scattering Theories and Dynamic Properties of Composite Materials
E SC	543	Laser Micro processing
E SC	545	Scientific and Engineering Foundations of Additive Manufacturing
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 Optoelectronic Devices and Applications
E SC	584	Introduction to Bio-Architecture
BIOE	512	Cell and Molecular Bioengineering
BIOE	517	Biomaterials Surface Science
CHEM	448	Surface Chemistry
CHEM	543	Polymer Chemistry
MATSE	400	Crystal Chemistry
MATSE	413	Solid-State Materials
MATSE	414	Mechanical Properties of Ceramics
MATSE	436	Mechanical Properties of Materials
MATSE	504	Solid State Materials
MATSE	507	Biomaterials Surface Science
BIOE	517	
Materials Cont'd: Select at least one course from the following list; each is a 3-credit course.		
MATSE	508	Biomedical Materials
BIOE	508	
MATSE	512	Crystal Chemistry
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, Mesoscale Simulations
MATSE	501	Thermodynamics of Materials
MATSE	503	Kinetics of Materials Processes
MATSE	512	Principles of Crystal Chemistry
<b>Engineering Science: Select at least one course from the following list; each is a 3-credit course.</b>		
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	
I E	552	
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	475	Particulate Materials Processing
E SC	481	Elements of Nano/Micro-electromechanical Systems Processing and Design
E SC	482	Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics
E SC	483	Simulation and Design of Nanostructures
E SC	484	Biologically Inspired Nanomaterials
E SC	501	Solid State Energy Conversion
E SC	502	Semiconductor Heterojunctions and Applications
E SC	505	Wearable Electronics
E SC	520	Engineering at the Nanoscale
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	536	Wave Propagation and Scattering
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

## 2.3 - Non-Thesis Master of Science Degree: Engineering at the Nanoscale

Practicing engineering at the nanoscale 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 requirements for one-year M.S. in Engineering at the Nanoscale are presented in Table 2-3.



**Table 2-3: Degree Requirements for One-Year Residence-Based M.S. Degree in Engineering at Nanoscale**

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 Nanoscale 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 (Table 2-4) 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 one-year residence-based Master of Science (M.S.) degree in Engineering at the Nanoscale 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 students making use of the facilities of the ESM Teaching/Videoining Nanotechnology cleanroom of the ESM Center for Nanotechnology Education and Utilization (CNEU) in their research. **NOTE: 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. Participation in a part of E MCH/E SC 514 seminar or ESC 515 course covering these issues is also encouraged.**

**It is the responsibility of the student and his/her adviser to make sure these requirements are met.**

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 nanoscale. **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 Nanoscale 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. A suggested plan of study is presented in Table 2-4. The core courses are as follows:

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

**Table 2-4: Plan of Study**

<b>Fall Semester (13 credits)</b>	
<b>E SC 412</b>	<b>Core 1 (3)</b>
<b>E SC 520</b>	<b>Core 2 (3)</b>
<b>E SC 521</b>	<b>Core 3 (3)</b>
<b>ELECTIVE</b>	<b>SELECT Elective (3)</b>
<b>E SC 596</b>	<b>Individual Study (1)</b>
<b>Spring Semester (13 credits)</b>	
<b>E SC 522</b>	<b>Core 4 (3)</b>
<b>E SC 523</b>	<b>Core 5 (3)</b>
<b>ELECTIVES</b>	<b>SELECT Electives (6)</b>
<b>E SC 596</b>	<b>Individual Study (1)</b>
<b>Summer Semester (4 credit)</b>	
<b>E SC 596</b>	<b>Individual Study (1)</b>
<b>ELECTIVE</b>	<b>SELECT Elective (3)</b>
<b>SARI requirements (5 hours) must be fulfilled in E SC 596.</b>	

### **Elective Courses:**

Four 3-credit electives in the program may be selected from any of the courses listed below. These courses can be arranged into three emphasis areas, Energy, Electronics and Photonics, and Materials (examples are listed in Table 2.5). 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.

- 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 Introduction to Bio-Architecture
- E MCH 597 (E MCH 543) Shape Memory, Smart Materials and Mechanical Behavior
- E MCH 544 Multiscale Modeling and Materials
- E MCH 597 (E MCH 545) Nanomechanics

### **Research Experience:**

- *E SC 596 Individual Study*

**Important:** The 596 Graduate Individual Studies form must be obtained from the graduate programs assistant, completed by student and faculty, signed and then returned to the graduate programs assistant for the course to be entered in LionPATH

**Table 2-5: Three Emphasis Areas**

<b>Energy Emphasis</b>	<b>Electronics and Photonics Emphasis</b>	<b>Materials Emphasis</b>
E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials	E SC 445 Semiconductor Optoelectronic Devices	E SC 414M Elements of Material Engineering
E SC 501 Solar Cell Devices	E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials	E SC 450 (MATSE 450) Synthesis and Processing of Electronic and Photonic Materials
E SC 502 Semiconductor Heterojunctions and Applications	E SC 482 Micro-Optoelectromechanical Systems (MOEMS) and Nanophotonics	E SC 481 Elements of Nano/Micro-electromechanical Systems Processing and Design
E SC 511 Engineering Materials for Energy Conversion and Storage	E SC 501 Solar Cell Devices	E SC 483 Simulation and Design of Nanostructures
E SC 551 (M E 551) High Power Energy Storage	E SC 502 Semiconductor Heterojunctions and Applications	E SC 541 Laser-Materials Interactions
E MCH 597 (E MCH 545) Nanomechanics	E SC 582 Micro- and Nano-Structured Light Emitting Devices	E SC 542 Laser-Integrated Manufacturing
CHEM 511 Chemical Nanoscience	E SC 583 Micro- and Nano-Optoelectronic Devices and Applications	E MCH 544 Multiscale Modeling and Materials
		E MCH 597 (E MCH 545) Nanomechanics
		Chem 511 Chemical Nanoscience

**Important note:** International students entering nano program are required to take AEOCPT test the first semester they are in residence. <https://aplmg.la.psu.edu/programs/about-the-aeocpt>

## 2.4 - Master of Engineering in Engineering Mechanics

Before starting or during the first week of the fall semester, students should investigate faculty research activities within the ESM department and contact faculty they are interested in working with so selection and discussion of the student's research project can begin as soon as possible. The scholarly 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.

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, 21 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 2-6.

**Table 2-6: Courses Credit Overview for M ENG Degree**

1.	Total (all courses including required)	31
2.	Analysis	3 (min)
3.	Fields	3 (min)
4.	Motion	3 (min)
5.	Materials	3 (min)
6.	E MCH/E SC 514 (Seminar)	1
7.	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 are 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 2-6. Table 2-7 shows the overall course and credit structure of the M ENG degree while Table 2-8 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 2-7: Required Courses Overview 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

**Table 2-8: Required Course Categories for M ENG Degree**

<b>Analysis</b>	<b>Fields</b>	<b>Motion</b>	<b>Materials</b>	
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 MCH 544
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 MCH 544	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	

**NOTE:** Students are required to devote at least 5 hours to learn about 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 best approach would be to participate in a part of E MCH/E SC 514 seminar covering these issues, in addition to the E MCH/E SC 514 seminar taken for 1 credit (= seminar taken in full for one semester and seminar's SARI part only in the following semester)

**Important: All Masters students (thesis and non-thesis options) and Nano and MEng MS need to have completed Written Communication Rubric submitted to Graduate Officer. The rubric is shown in Appendix A**

## **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 (IUG)**

Integrated Undergraduate/Graduate Study (IUG) status permits students to take on the rigors and research challenges of graduate study at Penn State while 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. Students interested in the IUG program should refer to section 2.1.1 to become familiar with the course and research credit requirements. Actual time 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 6<sup>th</sup> semester of expected conferral of the undergraduate degree**, as specified in the proposed IUG plan of study. It is important to contact the ESM Graduate Officer to start the process.

Example IUG Application Timeline assuming graduation in the 8<sup>th</sup> semester:

#### **During the 6<sup>th</sup> semester:**

- Student finds a research adviser and works with the adviser to develop the IUG research plan (see departmental website for faculty listing).
- Schedule a meeting with the ESM Graduate Officer to confirm interest in the IUG program and to review the completed IUG supplemental application form.
- Complete Application to the Graduate School and choose the 7<sup>th</sup> undergraduate semester as the semester for graduate admissions consideration. (to clarify: choose the first semester of your senior standing). Notify the graduate officer (graduate school does not contact ESM after the application is complete)



- The ESM graduate admissions committee will review the application and notify the student.
2. The application for IUG status should include the following information.
- a) An explicit plan of study leading to the M.S. Degree is required. The IUG supplemental application form must be filled and it can be found at: [https://sites.esm.psu.edu/wiki/\\_media/esm\\_iug\\_supplemental\\_application\\_form.pdf](https://sites.esm.psu.edu/wiki/_media/esm_iug_supplemental_application_form.pdf)  
NOTE: As many as 12 of the credits required for the master's degree may be applied to both undergraduate and graduate degree programs. Any 400 or 500 level engineering, math and/or science courses ***not required or used as foundational elective*** for the ESC BS degree can be double counted. 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.  
***Important:*** EMCH/ESC 496/596 independent study courses cannot be used for double counting
  - 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.
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 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. 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.
  5. 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.
  6. Students must fulfill basic undergraduate requirements first so that if, for some reason, they cannot continue in the integrated program they will be able to receive their undergraduate degree without a significant loss of time.
  7. In the semester in which the undergraduate degree requirements will be completed, IUG students must apply to graduate, and the undergraduate degree should be conferred at the next appropriate Commencement.
  8. 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(a), above, relative to 9 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
  9. 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.

**NOTE:** IUG students who wish to enroll into the Ph.D. program offered by the Department of Engineering Science and Mechanics at Penn State may do so only **AFTER** finishing the IUG Program. Students must complete ALL requirements for the M.S. degree (including submitting

and defending the Master's thesis) prior to starting their Ph.D. degree.

There are two forms concerning course selection:

- Supplemental form (available on ESM website) – must be submitted to Grad Officer and Grad Assistant when the IUG application is being initiated. It is essentially a plan of study for the whole IUG period. It should list courses a student, together with his adviser, select to be taken during IUG period. The undergraduate portion of it (senior year) will have double counted courses. This form will be submitted only once. Table 2-9 explains which courses can be listed on the form.
- Semester report (Table 2-10 – form on a Grad school website) - must be submitted every semester listing courses a student is actively enrolled in

**Table 2-9: Explanation of courses to be listed in IUG supplemental form**

### IUG Supplemental Application Form for Engineering Science Majors

This form **MUST** be completed and submitted to Engineering Science and Mechanics Graduate Officer

Name \_\_\_\_\_

Expected Graduate Date \_\_\_\_\_

Are you a Schreyer Honors Scholar?

☐ Yes

☐ No

#### Double-Counted Undergraduate/Graduate Courses (12 Credits)

**You need to be actively enrolled in the courses you are choosing for double counting**

The following course(s) should be counted toward both the baccalaureate degree and the master's degree. A maximum of 12 credits may be double-counted throughout the duration of the program and half

Course abbreviation and number	Credits
ESC or EMCH 4xx	3
ESC or EMCH 4xx	3
ESC or EMCH 5xx	3
ESC or EMCH 5xx	3

#### Graduate Courses Only (12 Credits)

The following course(s) should be counted toward the master's degree ONLY. (NOTE: These courses cannot count toward honors credits.) These courses must be 500 level

A total of 24 credits is required for the M.S. degree.

Course abbreviation and number	Credits
ESC or EMCH 5xx	3
ESC or EMCH 524A	3
ESC or EMCH 5xx	3
ESC or EMCH 5xx	3

Since identification of double-counted UG courses could be confusing here are important points:

- you cannot use FOUNDATIONAL ELECTIVES UNLESS they were NOT used to fulfill Engineering Science degree requirement
- you cannot use ANY REQUIRED COURSES -e.g. ESC 414, 404, 407, or 410.
- You cannot use any INDEPENDENT STUDY 496/596 courses
- You cannot use THESIS RESEARCH (600)/CAPSTONE EXPERIENCE

**Table 2-10: Example of IUG Semester report**

## Integrated Undergraduate/Graduate Semester Report

Office of Graduate Enrollment Services, The Pennsylvania State University, 114 Kern Building, University Park, PA 16802-3396; (814) 865-1795; (814) 863-4627(fax)

**This form MUST be completed each semester and submitted to Graduate Enrollment Services for final approval once all the signatures have been obtained.**

**The course information listed below relates only to** \_\_\_\_\_ **.**  
Semester/Year

\_\_\_\_\_  
Last Name First Name Middle Initial PSU ID

\_\_\_\_\_  
Undergraduate Degree Undergraduate Major Anticipated Semester/Year of graduation

\_\_\_\_\_  
Graduate Degree Graduate Major Anticipated Semester/Year of graduation

**Are you a Schreyer Honors Scholar?** ☐ Yes ☐ No

### Double-Counted Undergraduate/Graduate Courses

The following course(s) should be counted toward both the baccalaureate degree and the master's degree. A maximum of 12 credits may be double-counted throughout the duration of the program and at least half of all shared courses must be at the 500/800 level.

**Check with your program to determine how many credits you are permitted to double-count.**

Course abbreviation and number	Credits	Course abbreviation and number	Credits
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

### Graduate Courses Only

The following course(s) should be counted toward the master's degree ONLY. (NOTE: These courses cannot count toward honors credits.)

\_\_\_\_\_  
Signature of Student Printed Name Date

\_\_\_\_\_  
Signature of Graduate Program Head Printed Name Date

\_\_\_\_\_  
Signature of Undergraduate Program Adviser Printed Name Date

\_\_\_\_\_  
Signature of College Associate Dean for Undergraduate Education  
(From the College of the student's undergraduate major) Printed Name Date

\_\_\_\_\_  
Signature of Graduate School/Graduate Enrollment Services Printed Name Date

CC: Schreyer Honors College  
Registrar's Office  
Graduate Program

PENNSTATE \_\_\_\_\_ *The GRADUATE SCHOOL*



## 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 (see section 2.1) 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 qualifying 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 qualifying examination.

### 3.1 – The Qualifying Examination

Ph.D. students with only a B.S. degree (no M.S./M.ENG. degree) may take the Qualifying Examination after earning at least 18 credits beyond the baccalaureate degree, but NOT later than the third semester in residence, not counting the summer session. Courses eligible to be counted toward the graduate degree may be earned previously provided transfer credits for them are accepted. Ph.D. students with a M.S./M.ENG. degree must take the Qualifying Examination prior to the end of their second semester in residence, not counting the summer session. A student must have a GPA of 3.0 or greater for the work done at the University during graduate work. No incomplete or deferred grades are allowed. All students must be registered with either full-time or part-time degree status for the semester in which the Qualifying Examination is taken.

Students who have been identified as master's-along-the-way upon admission into the Ph.D. program must take the Qualifying Exam prior to the end of their second semester in residence, not counting the summer session, after completion of the M.S. degree. For students enrolled in a dual-title graduate degree program, there is a single Qualifying Examination combining both the primary graduate program and the dual-title field. The Qualifying Examination committee must include at least one member of the graduate faculty from the dual-title program. Students must be admitted to the dual-title degree program prior to taking the Qualifying Exam.

This examination is offered twice a year, during the first week of the fall and spring semesters

(August/September and January/February). The examination consists of two parts, a *Disciplinary Component* and a *Research Component*, both of which are administered by an Examination Board comprised of at least three tenure-track/tenured ESM faculty members in the ESM Department. Both the Disciplinary and Research Components consist of written and oral parts. There are five Specialty Tracks (see sections below). Each Board member serves a fixed term, with the term determined by that Specialty Track. The Board of each Specialty Track creates the examination and administers the oral part of the exam. *Each student must choose, in consultation with his/her research adviser, the Specialty Track for his/her Qualifying Examination.*

Near the end of each semester, typically during the week 10 of the semester, a Town Hall style meeting is scheduled so that all students considering taking the Qualifying Exam the next semester can meet with the Specialty Exam Chairs and ask specific questions about topics, format, etc. Students are NOT permitted to consult about the Qualifying Exam with any faculty member who is submitting questions for the exam.

### 3.1.1 – Disciplinary Component (4 hours)

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

The broad coverage of each Specialty Exam is intended to provide an evaluation of the fundamental knowledge required for advanced study in the student's chosen field within Engineering Science and Mechanics. Exams may be structured to give students some choice in the questions that must be answered in order to pass, based on the emphasis of a specific number of subdomains within each specialty area.

To guide student preparation, a detailed list of topics, courses and books indicative of the scope and level of questions on all Specialty Exams is made available by each Board in the Town Hall style meetings. Students are strongly advised to attend these meetings, even if considering the Qualifying Exam in a future semester.

**Mechanics:** This exam may include the following subject areas: mechanics of materials; elasticity, continuum mechanics, dynamics, vibrations, 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. More details on topics and recommended books for study can be found in Appendix B. Examples of courses covering topics in mechanics are given in Table 3-1.

**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. Some questions will be from topics covered in three graduate level courses in materials taken by the students. More details can be found in Appendix E. Some examples of

courses are given in Table 3-1.

**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. More details on topics and recommended books for study can be found in Appendix C. Examples of courses covering topics in electromagnetism are given in Table 3-1.

**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 and will be from topics covered in three graduate level courses in bionanotechnology taken by the students. Courses in bionanotechnology are listed in Table 3-1.

**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. and will be from topics covered in the courses given in Table 3-1. More details can be found in Appendix D.

**Table 3-1: Examples of courses that cover topics that may be considered for the qualifying examination; this list is NOT exhaustive.**

Qualifying Specialty	Courses
<b>Bio/Nanotechnology</b>	EMCH 471 – Engineering Composite Materials E SC 400H – Electromagnetic Fields 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 497 – Advanced Biofabrication Processes E SC 505 – Wearable Electronics BIOE 510 – Biomedical Applications of Microelectromechanical Systems (BioMEMS) and Bionanotechnology

	E SC 503 – Low Dimensional Nanoelectronics E SC 518 – Bioprinting E SC 520 – Engineering at the Nanoscale E SC 521 – Pattern Transfer at the Nanoscale E SC 522 – Fabrication and Characterization for Top-Down Nano-Manufacturing E SC 523 – Fabrication and Characterization for Bottom-Up Nano-Manufacturing E SC 582 – Micro- and Nano-Structured Light Emitting Devices E SC 583 – Micro- and Nano Optoelectronic Devices and Applications E SC 584 – Introduction to Bio-Architecture
<b>Electromagnetism</b>	E SC 400H – Electromagnetic Fields E SC 536 – Wave Propagation and Scattering E SC 540 – Laser Optics Fundamentals E SC 582 – Micro- and Nano-Structured Light Emitting Devices EE 522 – Electro-Optics Laboratory EE 420 – Electro-Optics: Principles and Devices EE 422 – Optical Engineering Laboratory
<b>Materials</b>	E SC 414M – Elements of Material Engineering E SC 419 – Electronic Properties and Applications of Materials E SC 445 – Semiconductor Optoelectronic Devices E SC 577 – Engineered Thin Films MATSE 514 – Characterization of Materials MATSE 501 - Thermo Materials ESC 597 - Electron Resonance EE 542 - Semiconductor Devices MATSE 504 - Solid State Materials ESC 522 - Fabrication and Characterization for Top-Down Nano-Manufacturing
<b>Mechanics</b>	E MCH 500 – Solid Mechanics E MCH 507 – Elasticity E MCH 520 – Advanced Dynamics E MCH 521 – Stress Waves in Solids E MCH 530 – Mechanical Behavior of Materials E MCH 540 – Introduction to Continuum Mechanics E MCH 571 – Foundations of Structural Dynamics and Vibration
<b>Neural Engineering Science</b>	E SC 525 - Fundamentals of Interfacing with Brain Neuro 520 - Molecular and Cellular Neuroscience Neuro 521 - Systems Neuroscience E SC 400H - Electromagnetic Fields E MCH 524A - Mathematical Methods in Engineering E SC 555 – Fundamentals of Data Analysis in Neuroscience

### 3.1.2 – Research Component

This section contains guidelines for writing the research proposal.

The Research Component of the Qualifying Exam consists of a research proposal and an oral



presentation on an “Emerging Technology.” *This part of the exam tests the student’s ability to think critically, to plan a research project, as well as written and oral communication skills in English.* Research topics are intended to assess how well a student meets the beginning stages of the first five program learning objectives (know, create, apply, communicate, and critical thinking; see Section 3.8 for details). As such, the Chair of each Specialty Examination Board, in consultation with the members of their Board, assigns an appropriate topic to each student immediately after the written part of the Disciplinary Exam. Once the topic is assigned, the proposal preparation is the sole effort of the individual student and the Penn State academic integrity policy is in force. Students may consult with experts on the topic specific questions. However, these experts need to be acknowledged in the proposal and they cannot be involved with reviewing ideas, planned tasks, or writing. Regardless of the nature of the topic, the proposal should approach the topic from the standpoint of the particular Specialty; i.e., mechanics, materials, electromagnetics, bionanotechnology, or neural engineering science. The Research Component provides an assessment of the student’s competence in the use of the English language including reading, listening, writing and speaking. Remedial coursework to attain proficiency in English may be prescribed. The Qualifying Exam is evaluated according to the requirements of the Middle States Commission on Higher Education Accreditation: <https://opair.psu.edu/assessment>.

The oral part of the Qualifying Exam covers both disciplinary and research components and takes place within one week of submission of the research proposal. The oral part of the exam generally does not exceed 90 minutes. It is composed of a 20-minute presentation of the proposal followed by a question-and-answer period related to the proposal as well as follow-up to the Disciplinary Exam.

*The student’s research adviser is strongly encouraged to join the Examination Board as a non-voting member but cannot be the sole participant in the formal assessment of his/her student. If the adviser is already a member of the Examination Board, he/she is not permitted to vote, and, if needed, another ESM graduate faculty member is asked, temporarily, to act as a voting member.*

### **3.1.2.1 - Research Proposal Guidelines**

This section contains guidelines for preparing the research proposal presentation.

Write a research proposal on the topic assigned to you. The scope of the proposed project is that you alone will work on it for two years. The proposal shall be comprised of a title, author name, and the following sections: problem statement, research objective statement, research plan, intellectual merit, impact, and bibliography. The proposal should be single-spaced, font size 12, 1” margins and 6 pages in length including graphics, tables, and bibliography. All Penn State Academic Integrity policies (see Senate Policies 49-20 and G-9) apply to the Qualifying Exam in general and the research proposal in particular. Academic Integrity violations will result in failure of the exam. Students will submit their research proposal through TurnItIn on Canvas.

Topic: This is the description of the ESM-based topic for the student to investigate. It’s typically one paragraph long. It may include some references to provide a starting point. Historically, we have given each student a unique topic that is outside of their realm of expertise. It is now proposed to give topics in line with the student’s intended research topic, but not that topic itself.

#### **1. Problem Statement**

Write a critical assessment of the topic assigned to you. In preparing your critical assessment you should do the following. (a) Research the topic. (b) Re-write the topic in your own words as a problem



statement that includes: (c) description of the current knowledge, the applicable fundamental laws and operative assumptions; (d) discussion of the analysis methods, computational models, and experimental techniques appropriate to this specific topic. (e) Conclude by identifying the gaps in knowledge, or at least the ones you are proposing to fill. (f) Cite references throughout your assessment.

## 2. Research Objective Statement

Write a research objective statement based on your critical assessment above. The objective statement should form the basis for a self-directed research project that you would undertake. It should be clear from your research objective and problem statement how your proposed research fits into the current body of knowledge in the area of your specialty exam.

## 3. Research Plan

Develop a research plan that defines the tasks that you are proposing to perform. Students are encouraged to follow instructions from the National Science Foundation regarding the research plan. “The Project Description should outline the general plan of work, including the broad design of activities to be undertaken, and, where appropriate, provide a clear description of experimental methods and procedures. Proposers should address what they want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful.”<sup>1</sup>

Note that the last phrase about benefits should be addressed in Section 5. Impacts.

## 4. Intellectual Merit

Describe the intellectual merit (i.e., the potential to advance knowledge) of your proposal.

## 5. Impact

Describe the impact that you expect this research to have on the ESM department and society; i.e., “...what benefits could accrue if the project is successful.”

## 6. Bibliography

List the references that you have cited in a standard format.

### 3.1.2.2 - Presentation Guidelines

Prepare a 20-minute oral presentation of your proposal to present to the Examination Board. It is standard practice to use slides to guide the audience through your presentation. The number of slides can vary, but a reasonable rule-of-thumb is to cover 1 slide per minute. Your title slide gives you a chance to preview your presentation and grab the attention of the audience. For this presentation, the audience knows the problem statement, so state your research objective on the second slide. Then go back and assure the audience that you understand the problem well by giving a critical assessment of the literature and description of the knowledge gaps. Now affirm how your research objective fills knowledge gaps and solves problems and takes advantage of opportunities. The stage is now set to outline your research plan; describe the methods and tools that you will use, as well as expected challenges and how they will be overcome, provide a timeline. Close the presentation by highlighting the intellectual merit of the proposed research and state the expected impact. It is often helpful to have some backup slides ready to help answer questions (key references, more details on an experimental procedure or equation development, etc.). Make sure that you follow academic integrity guidelines and attribute pictures, equations, figures, etc. to the proper source.

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<sup>1</sup> The National Science Foundation, “Proposal and Award Policies and Procedures Guide, NSF 20-1, Effective June 1, 2020.

1. Title – 1 slide
2. Research objective – 1 slide
3. Critical assessment of literature ~ 4 slides
4. Knowledge gaps ~ 4 slides
5. How you plan to solve the problem, challenge, or opportunity ~ 4 slides
6. Research plan ~ 4 slides
7. Intellectual merit – 1 slide
8. Impact – 1 slide
9. Backup slides

### 3.1.3 – Evaluation of the Qualifying Exam

During the second week of every semester, all the Examination Boards jointly conduct an open Town Hall style meeting to advise doctoral students on the scope of the Qualifying 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 Qualifying Exam and makes a pass/fail recommendation to the entire ESM Graduate Faculty, which makes the final decisions. In order to pass the Qualifying Exam a student has to score at least 70% on the written portion of the exam and his/her research proposal has to be accepted by the Examination Board. The Board may also recommend, that a student take certain additional courses including remedial education to improve English competency, regardless of the outcome of the exam. English competence needs to be formally attested before the doctoral student's comprehensive examination is scheduled (see section 3.4)

A student who does not pass the Qualifying 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 not becoming a Ph.D. candidate.

The Qualifying Exam Evaluation rubric is presented in Appendix F.

## 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, as well as administering the oral comprehensive and the final oral examination. ***After notification about the successful completion of the Qualifying Exam, the student should form the doctoral committee within one year.*** 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. 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 serve as the outside field 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.

As soon as the committee is formed students should contact the graduate programs assistant to complete the Doctoral Committee paperwork.

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 semester of the formation of the committee. Following this, the entire Ph.D. Committee should meet together with the student to conduct annual assessment, or if this arrangement is impossible, the student should meet individually with each member, at least annually. The meeting may be requested by the student or any member of the committee. The Ph.D. Committee's assessment report should be shared with the student and include his/her comments on the report. The completed annual assessment must be submitted by the Ph.D. Committee Chair to the Graduate Program Head.

### 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 B.S. (or equivalent) or M.S./M.ENG. degree as follows:

1. Students may enter the Ph. D program after completing an M.S. degree or directly from the B.S. degree; the student starting from the B.S. degree will have a higher number of required credits.
2. The minimum number of course credits required for students entering the PhD program with a baccalaureate degree (see **Table 3-2A**):
  - a) A student must earn at least 27 course credits in 400- and 500- level lecture/laboratory courses approved by the department, and 5 credits in a graduate seminar (E MCH/E SC 514). No more than 6 of the 27 course credits can be in 400-level courses. As part of the 27 course credits, at least 3 will be in an advanced mathematics course (E MCH 524A or equivalent). Furthermore, at least one course (of at least 3 credits each) must be taken from each the following three categories: Mechanics, Materials, and Engineering Science (see Table 2-2).
  - b) A minimum of 15 course credits must be in the major (courses with E MCH and/or E SC prefixes).
  - c) A student must satisfy the seminar credit requirements for a total of 5 credits of ESC 514
  - d) Twelve credits of letter grade Thesis Research with E MCH/E SC 600 designation are required. Students are allowed to register for E MCH/E SC 600 credits beyond the 12 required, but these credits will receive a grade of "R" if successfully completed. Students are allowed to register for E MCH/E SC 600 credits only before passing the Comprehensive Examination, after which they must register for E MCH/E SC 601 for 0 credits.
3. Nine credits taken during each fall and spring semester (for students on half-time assistantships) should consist of course or research credits until the student has met the residency requirements (see section 3.5) of the Graduate School and has passed the comprehensive examination.
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 student pursuing the Ph.D. degree program directly from a B.S. (or equivalent) degree (hence, no M.S./M.ENG. 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. A student identified as master's-along-the-way upon admission into the Ph.D. program must fulfill **ALL** requirements of the M.S. degree and may take the qualifying exam after the completion of the M.S. degree (see section 3.1).

**Table 3-2A: Ph.D. Degree Requirements – Engineering Baccalaureate Degree Holder**

<b>Minimum number of course credits</b>	<b>27</b>
<b>Graduate seminar (E MCH/E SC 514)</b>	<b>5</b>
<b>Research credits (E MCH/E SC 600)</b>	<b>12 credits of letter grades (additional research credits are allowed but without a letter grade)</b>
<b>Minimum number of total credits</b>	<b>44</b>
<b>Core courses required</b>	E MCH 524A or equivalent, plus one course (of at least 3 credits) from each category: Mechanics, Materials, and Engineering Science
<b>Maximum number of credits in 400-level courses</b>	<b>6</b>
<b>Minimum number of course credits at 500 level</b>	<b>21</b>
<b>Minimum number of E MCH/E SC credits</b>	<b>15</b>
<b>Qualifying examination</b>	After earning 18 course credits (post B.S.) and no later than the 3 <sup>rd</sup> semester in residency (not counting the summer session).
<b>Comprehensive examination</b>	Passed qualifying examination, have a minimum of 3.00 GPA, and satisfied the English competence  Ideally it should be done the first semester following passing the QE
<b>Culminating experience</b>	Completion of dissertation and oral defense

6. As stated in Section 2 (see **Table 2-1**), 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. In addition, for a student entering PhD program with a M.S. degree:

- a) at least 18 graduate credits must be earned in 400- and 500- level lecture/laboratory courses approved by the department (only two 400 level courses may be taken)
- b) 3 credits of a graduate seminar (E MCH 514 or E SC 514) must be earned beyond the master's degree requirements

Table 3-2 B summarizes the above requirements.

**Table 3-2B: Ph.D. Degree Requirements – M.S. Degree Holder**

<b>Minimum number of course credits</b>	<b>18</b>
<b>Graduate seminar (E MCH/E SC 514)</b>	<b>3</b>
<b>Research credits (E MCH/E SC 600)</b>	<b>12 credits of letter grades (additional research credits are allowed but without a letter grade)</b>
<b>Minimum number of total credits</b>	<b>33</b>
<b>Core courses required</b>	No special requirements
<b>Maximum number of credits in 400-level courses</b>	<b>6</b>
<b>Minimum number of course credits at 500 level</b>	<b>12</b>
<b>Minimum number of E MCH/E SC credits</b>	<b>12</b>
<b>Qualifying examination</b>	no later than the 3 <sup>rd</sup> semester in residency (not counting the summer session).
<b>Comprehensive examination</b>	Passed qualifying examination, have a minimum of 3.00 GPA, and satisfied the English competence  Ideally it should be done the first semester following passing the QE
<b>Culminating experience</b>	Completion of dissertation and oral defense

Initially, courses can be chosen from the list of suggested courses for the written component of the qualifying examination given in Table 3.1 (see sub-section 3.1.1).

### 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.*** That level of competence will be assessed through requiring a candidate to provide original writing (of a sufficient length and complexity) on a subject outside candidate's technical expertise and presenting and discussing this topic with a broad audience. This task will be achieved by writing a report on one of the ethics topics presented in the EMCH 514 seminar. Each candidate will be required to present and discuss his/her report during the first available date of the seminar meeting times. Each candidate will receive a grade on the written report and corresponding oral presentation which will be used to assess candidate's level of English language competence. If necessary, remedial course work and the use of the services of the English for Professional Purposes Intercultural Center (EPPIC) will be prescribed to the candidate.

### 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 consecutive semesters, **exclusive of summer sessions**, as a registered full-time student engaged in academic work on the University Park Campus. **This Residency Requirement must be satisfied prior to the semester in which the final oral examination is administered.**

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 MCH/E SC 601, or E MCH/E SC 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/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 until all course activities are finished including the Final Exam period. For Fall semesters, the start date is typically 1 week before the start of classes and the end date may extend a week after classes end. Failure to be on campus during this period is grounds to have the TA contract and all support terminated.**

### 3.6-The Comprehensive Examination

1. The candidate must have passed the qualifying exam and his/her English language



competence must have been formally attested before taking the comprehensive examination.

2. The Comprehensive Examination may not occur before the completion of all course work required by the program and the Ph.D. Committee; it should be scheduled as quickly as possible following the passing of the Qualifying Examination.
3. 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. A written proposal of the intended thesis research will be required in advance of the oral part of the comprehensive examination
4. The responsibility for scheduling the Comprehensive Exam rests with the student and their Ph.D. committee chair.
5. The comprehensive examination may be held fully in-person or with partial remote participation. The student, adviser, and Ph.D. Committee Chair/Co-Chairs must be physically present for the examination. Other members of the Ph.D. committee may participate remotely with the agreement of the student and adviser. If the student, adviser, and/or committee chair/co-chair is not able to participate in-person due to extenuating circumstances, the Graduate Program Head may approve at their discretion the remote participation of one or more individuals or approve a fully remote examination.
6. The Graduate School requires a minimum of **two (2) weeks'** notification and hence, the candidate must contact the graduate programs assistant 3 weeks in advance to do the paperwork for comprehensive exam. If the candidates committee has not been officially formed, the candidate must contact the graduate programs assistant **4 weeks** in advance. Failure to have this done in the required time-frame may cause the exam to be delayed until the following semester.
7. 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.
8. 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.
9. The student must be registered as a full or part-time degree student for the semester in which the comprehensive examination is taken.
10. A favorable vote of at least two-thirds of the members of the Ph.D. committee is required for passing the Comprehensive Examination.
11. A student who does not pass the Comprehensive Examination on the first attempt may be permitted by their Ph.D. committee to retake the examination, in its entirety. 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) and leave the program.

### **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. The responsibility for scheduling the Final Oral Examination rests with the student in consultation with their Ph.D. committee chair.

The final oral examination (dissertation defense) may be held fully in-person or with partial remote participation. The student, adviser, and Ph.D. Committee Chair/Co-Chairs must be physically present for the examination. Other members of the Ph.D. committee may participate remotely with the agreement of the student and adviser.

If the student, adviser, and/or committee chair/co-chair is not able to participate in-person due to extenuating circumstances, the Graduate Program Head may approve at their discretion the remote participation of one or more individuals or approve a fully remote examination.

Once the date of the exam is finalized, the candidate needs to contact the graduate programs assistant 2.5 weeks in advance for the paperwork to be done.

Normally, the examination may not be scheduled until at least 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:

The final oral examination shall consist of a public oral presentation of the dissertation followed by a closed discussion between the student and the student's Ph.D. Committee.

1. The presentation should be delivered 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. The presentation should proceed without interruption from the audience.
4. 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.

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. The doctoral committee will also determine if there is a limit on number of attempts, and in case of failure of the final attempt, if a student is allowed to change to the master's degree or will be dismissed from the program.

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.

The student is responsible for providing a copy of the dissertation to each member of the Ph.D. committee at least two weeks prior to the scheduled date of the final oral examination.

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.

The dissertation must meet editorial standards specified by the Graduate School so that it constitutes an official University record for inclusion in the University Libraries and to be available to the public.

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: <https://gradschool.psu.edu/completing-your-degree/thesis-and-dissertation-information/> Copies may be purchased at the Thesis Office, 211 Kern Building. Costs incurred with thesis binding are the responsibility of the student.

Taking both the dissertation and the final oral examination into consideration, the Ph.D. Committee evaluates the accomplishments of the student relative to the program's defined Learning Objectives, particularly with respect to the student's mastery of the major.

<b>Program Learning Objectives (PLO)</b>
<b>1. Know:</b> Graduates will demonstrate an in-depth knowledge of the core theories and methods within one or more sub-specialties in the fields of engineering science and mechanics. The core demonstration will include the application of physics, advanced mathematics and engineering principles to problems in mechanics, materials, bionanotechnology, nanoscience and neuroscience.
<b>2. Create:</b> Graduates will be able to synthesize theory, literature and experimental results to generate new concepts, designs or hypotheses in engineering science and mechanics.
<b>3. Apply:</b> Graduates will be able to carry out independent and original research studies that address current problems in the multi-disciplinary field of engineering science and mechanics.
<b>4. Communicate:</b> Graduates will be able to convey ideas or arguments in clear, concise, well organized papers and proposals as well as in formal, oral presentations.
<b>5. Critical Thinking:</b> Graduates will be able to critically analyze work by others in their field of specialty.
<b>6. Professional Practice:</b> Graduates will demonstrate the ability to collaborate in a collegial and ethical manner with other professionals within their field and/or with diverse scientific backgrounds

### 3.9 – Time Limitation

A doctoral student is required to complete the program including acceptance of the doctoral thesis within eight years (not including approved leave of absence) from the date of acceptance as a candidate (= successful completion of QE).

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-4 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 514 (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. Qualifying Exam · given twice yearly (August/September and January)
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 semester of formation
5. Preparation of research objectives
6. Fulfillment of course requirements
7. Residency requirement · nine (9) credits minimum
8. Comprehensive exam · after completion of all course work required by the program and the Ph.D. Committee-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 qualifying 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 qualifying examination 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.

Joint M.D./Ph.D. candidates should apply to the Ph.D. program in Engineering Science and Mechanics in spring of M2. 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. However, there are some exceptions:

- If students accepted into the joint degree program are unable to complete the M.D. degree, they are still eligible to receive the Ph.D. degree if all Ph.D. requirements have been satisfied
- students admitted to the program with a baccalaureate degree will be allowed to double count 9 professional credits (21% of the total graduate credits) toward graduate course credit for the Ph.D. ESMCH degree;
- 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 Qualifying 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 Qualifying 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 Qualifying Examination within 3 semesters of entry into the Ph.D. program (expected to be the Fall Semester of G2).

Upon successfully completing the Qualifying 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 Qualifying 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)**

Students may enter the Ph.D. program after completing an appropriate baccalaureate or master's degree prior to admission.

As detailed in Chapter 3, candidates for the Ph.D. degree in Engineering Science and Mechanics typically take a minimum of 44 total credits beyond the baccalaureate degree (27 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 must demonstrate English proficiency, pass a Qualifying 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 4<sup>th</sup> 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 Qualifying 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 9 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.
- 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 21 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 Qualifying 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 Qualifying 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 Qualifying Examination within 3 semesters of entry into the Ph.D. program (expected to be the Fall Semester of G2).
- Upon successfully completing the Qualifying 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 Qualifying 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) 9 credits of professional medical course work (21% 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, credits from the following courses could be double counted: BMS 506 A (2 credits), BMS 506B (2 credits), and either HMN 713 (Medical Humanities; 5 credits) or SHS 711 (Health systems; 6 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	
<b>M1</b>	MD Curriculum (25 professional credits)	MD Curriculum (26 professional credits)	9	Professional
	Professional Course (dual graduate credits: 9)			
<b>Summer</b>	E SC/E MCH 596 or E SC/E MCH 600 Laboratory Rotation (3 graduate credits)		3	Graduate
<b>M2</b>	MD Curriculum (32.5 professional + 2 graduate credits)	MD Curriculum (33 professional + 2 graduate credits)		
<b>G1</b>	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
<b>G2</b>	ESM Approved Graduate Courses (10 credits)	E SC/E MCH 600/610 Research (6 credits)	12	Graduate Research
<b>G3-GX</b>	E SC/E MCH 600/610 Research (3 credits)	E SC 601 Thesis Preparation (0 credit)		
<b>M3</b>	MD Curriculum (~36 credits)	MD Curriculum (~36 credits)		
<b>M4</b>	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)		44	<b>Total</b>

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	
<b>M1</b>	MD Curriculum (25 professional credits)	MD Curriculum (33 professional credits)	7	Professional
	Professional Course (dual graduate credits: 7)			
<b>Summer</b>	E SC/E MCH 596 or E SC/E MCH 600 Laboratory Rotation (3 credits)		3	Graduate
<b>M2</b>	MD Curriculum (34.5 professional credits)	MD Curriculum (35 professional credits)		
<b>G1</b>	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)	2	Seminar
<b>G2</b>	E SC/E MCH 600/610 Research (6 credits)	E SC 601 Thesis Preparation (0 credit)	6	Research
<b>G3-GX</b>	E SC 601 Thesis Preparation (0 credit)	E SC 601 Thesis Preparation (0 credit)		
<b>M3</b>	MD Curriculum (~36 credits)	MD Curriculum (~36 credits)		
<b>M4</b>	MD Elective Credits (~10 credits)	MD Elective Credits (~11 credits)		
	5 credits E SC/E MCH 600/610 from G2 (dual professional credits)		33	Total

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 Qualifying 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 Qualifying 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 Qualifying 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 not required for admission.

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.

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. Additionally, the student must remain until all course related activities are finished including the grading of final exams and/or projects; this usually extends to the finals week after classes have ended. Failure to be on campus during the required time period 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 (regardless if 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, and/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 Session
	None	15-18	5-12
¼ time	10	9-14	5-7
½ time	20	12	4-6
¾ time	30	6-8	3-4

\*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.

*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, project, and/or 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 while in the U.S.. 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.  |
| 200-249   | Enroll in <b>ESL 118G</b> <i>before</i> 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>  |
| 150-199   | Enroll in <b>ESL 117G</b> . 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 150 | Enroll in <b>ESL 115G</b> 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 notified by the department of the date of your test. Depending on your score, you may be required to take additional English coursework.**

**For more information about the AEOCPT test, please visit**  
<https://aplng.la.psu.edu/programs/about-the-aocpt>

**\*\*Note: The Qualifying 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>



## Chapter 14: Important Deadlines for Fall and Spring

<b>Deadlines by Semester</b>	<b>Fall 23</b>	<b>Spring 24</b>	<b>Summer 24</b>
Apply to Graduate in LionPath	9/5	01/22	TBD
Submit doctoral presentation for format review	10/2	02/05	
Submit master's thesis for format review	10/2	02/05	
Pass doctoral defense	10/09	02/23	
Submit final thesis or dissertation and supporting materials	11/03	03/18	
Committee members to approve final thesis/dissertation	11/10	03/25	

## Questions graduate students frequently ask

What courses should choose?

*Talk to your research adviser, follow recommendations for specific degree (tables 2.2 – graduate guide pp.12-16)*

What if my adviser not from ESM?

*Find a co-adviser in the ESM department*

When to schedule comprehensive?

*When you complete all your courses;*

*– if scheduled for summer it needs to be completed before first day of classes,*

*- you need to be registered for the semester you have your comp (so for summer the best is to register for EMCH/ESC 600 for 1 credit)*

IUG students – what if I do not graduate (B.S.) in time?

*Due to extenuating circumstances – Grad Officer may write a memo to grad school asking for extension*

While on RA – does 9 credits requirement include research credits or just courses?

*Both may be used to reach 9*

Are there any limits for GRE?

*No GRE required at the moment, no cut off score*

What are research credits courses?

*12 credits for PhD; 6 for MS; only 6 letter grades allowed, the remaining must be awarded 'R'*

*Post -comprehensive students should be registered for EMCH/ESC 601 at zero credits. If you have not passed your comprehensive, you should be registered for EMCH/ESC 600 NOT 601. \*you should NEVER schedule an EMCH/ESC 600 or 601 course that does not have a faculty member listed or has staff listed as the instructor. If you do not see your research advisor listed for any section of EMCH/ESC 600 or 601, please contact Tammy Coval and she will have them added to a section so you are able to register for the course you need.*

Deadlines for scheduling final defense, intent to graduate, submission of written thesis, ..etc.

*please check on grad school website since these dates are fixed and differ from year to year : <http://gradschool.psu.edu/completing-your-degree/thesis-and-dissertation-information/thesis-dissertation-performance-and-oral-presentation-deadlines-calendar/>*

What to do if I haven't completed SARI

*Requirements for SARI <https://www.research.psu.edu/training/sari> consist of: CITI online, plus ORP workshops <https://www.research.psu.edu/orp> (2hr) plus ESC 514 or ESC 515 (ethics discussion parts) – 3 hr.*

*Workshops are offered throughout the year and you may find some that are suitable for you. To make up 3 hr of in-person discussion you may find more workshops through different departments at PSU or/and ORP. Usually, Graduate Officer requires that you send him the detailed report of your analysis*

*NOTE: it is the student's responsibility to meet all SARI requirements. Failure to do so will result in a delay of graduation until all credit hours are satisfied.*

MS defense

*schedule defense, notify Tammy about the date and time, follow recommended format (non-technical abstract as appendix) and be aware of deadlines*

Ph.D. and MS?

“I was wondering what do I need to do in order to get a Master's degree? I am currently in Ph.D. program; however, I have already completed required course work to pursue a Master's Degree including graduate seminars. I heard that I can get both Master and Ph.D. degrees since I started directly Ph.D. without having a master”.

*As soon as the PhD student decides to pursue an MS, the master's degree should be added to the record. This can be done by emailing the appropriate [Records Team enrollment coordinator](#). The Graduate School Application cannot be used to add a concurrent degree. Initiating a Change of Degree would either remove the student from the PhD or add the master's degree only after the PhD was conferred. BUT- this procedure is discouraged by the Grad School. The best practice is to enroll in a program as 'master's-along-the-way' option.*

“Do I need to write a thesis, or could I count one of my first author published paper, which would be different than my Ph.D. main work?”

*It depends what MS track you choose -for a non-thesis one your scholarly paper will be enough, for a thesis option you will need to write one.*

“I don't have any Graduate class that am going to take since I still need to take their prerequisite and the double counted course I choose is only offered in spring. Do I leave the course section of

the semester report blank or I have to take some course count towards IUG program each semester?”

*Since the double counted courses require two at the 400 level, take these.*

**IUG:**

For the 2022/2023 academic year (graduating with a B.S. Spring 2023), is my starting semester of my MS Degree Summer of 2023 or fall of 2023?

*While the MS portion starts in the Fall 2023, you will be starting the program (IUG) Fall 2022*

The program name: I have it filled in at Engineering Science and Mechanics. Is that correct?

*yes*

Transcripts: I am just double checking that I DO NOT need an official transcript from Penn State to apply for the IUG program?

*The transcripts are being pulled out for PSU students so you don't need to officially request them*

How can I tell if I am graduating with an honors degree?

*It will be determined at the time of your graduation (spring 2023), depending on your GPA (has to be 3.3 or better) and it will be stated on your diploma*

I was told that I do not need to take the GRE to apply for this program. Do I just leave the test scores section blank?

*Yes*

For course work to be completed. I have not selected my final two technical electives, 9 credits of electives and 1.5 credits of physical credits. Do I have to pick those now or can I just write this exact description I just wrote?

*Need to select and submit on your supplemental application anyway, right now just list courses you have taken in spring 2022 and some of you are intending to take in the fall 2022*

Can my references be the same professors that I have asked to write my letters of recommendation or must they be different?

*Yes, but one needs to be your senior (and then M.S.) research advisor*

What are the advantages and disadvantages of waving or not my right my right for the release of information from my educational record?

*Most students wave it – it makes the recommendation letters more meaningful*

In work experience, If I am currently working somewhere how do I denote this in the application

*state the dates...from....to present (employment category)*

I am very confused at what both of the program specific questions mean and could use clarification on both of their meanings.

*Answer no to stay in ESMCH*

*Choose a proper track (non-thesis or thesis)*

# **APPENDIX A: Written Communication Rubric for Masters Degrees (M.S. Engineering Science and Mechanics, M.S. Engineering at the Nanoscale. M. Eng. in Mechanics)**

To be Completed by the Research Adviser after the Oral Presentation of the Thesis

Candidate: \_\_\_\_\_

Date: \_\_\_\_\_

Adviser \_\_\_\_\_

	Excellent	Very Good	Satisfactory	Unsatisfactory
Context and Purpose for Writing the Thesis or Scholarly Paper  <i>Circle one of the four boxes →</i>	Demonstrates a thorough understanding of context, audience and central purpose (hypothesis, design) of the document.	Demonstrates adequate understanding of context, audience. The central purpose (hypothesis, design,) is clearly defined.	Demonstrates awareness of context, audience and purpose. The central purpose (hypothesis, design,) is clearly defined.	Demonstrates minimal consideration of context, audience, purpose.
Document Organization  <i>Circle one of the four boxes →</i>	Demonstrates detailed attention to and successful execution of important conventions that are appropriate to the writing tasks of the engineering and science disciplines for basic organization, content and presentation.	Demonstrates consistent use of important conventions that are appropriate to the writing tasks of the engineering and science disciplines for basic organization, content and presentation.	Follows expectations appropriate to the writing tasks of the engineering and science disciplines for basic organization, content and presentation.	No Attempt to use a consistent system for basic organization and presentation.
Technical and Scientific Content  <i>Circle one of the four boxes →</i>	Uses appropriate, relevant and compelling content to illustrate a mastery of the subject throughout the document.	Uses appropriate and relevant content to illustrate a reasonable command of the subject.	Uses appropriate and relevant content to explore ideas through a preponderance of the work.	Does not use relevant content to develop and explore technological and scientific concepts.

Sources and Evidence  <i>Circle one of the four boxes →</i>	Demonstrates skillful use of relevant and high-quality sources to support ideas that are appropriate for the discipline and genre (thesis or scholarly paper) of the writing.	Demonstrates consistent use of relevant and high-quality sources to support ideas that are appropriate for the discipline and genre (thesis or scholarly paper) of the writing.	Demonstrates an attempt to use credible and/or relevant sources to support ideas that are appropriate for the discipline and genre (thesis or scholarly paper) of the writing.	Does not demonstrate usage of relevant sources from literature.
Control of Syntax and Grammar  <i>Circle one of the four boxes →</i>	Uses straightforward language that generally conveys meaning to readers. The language in the document has few errors.	Uses language that generally conveys meaning to readers with clarity, although writing may include some errors.	Uses language that sometimes impedes meaning because of errors in grammar.	Uses language with serious grammatical errors that limits the communication of technical and scientific concepts.

Total Assessment (circle one) =    Excellent,    Very Good,    Satisfactory,    Unsatisfactory

Written Comments by the Adviser:

Adviser Signature \_\_\_\_\_ Student Signature \_\_\_\_\_

\_\_\_\_\_



## APPENDIX B: QUALIFYING EXAM: DISCIPLINARY COMPONENT IN MECHANICS

The exam assesses students across the full scope of mechanics, divided into in the broad areas of *solids* and *motion*. Each exam consists of a total of fourteen problems, two each in the following seven areas:

- **Solids**
  - strength of materials
  - elasticity
  - continuum mechanics
- **Motion**
  - dynamics
  - vibrations
  - waves
- **Applied mathematics**

Out of the fourteen problems, students are required to answer:

- Two solids problems
- Two motion problems
- Two other problems, only *one* of which can be an applied math problem

Exactly six problems will be graded. Each problem is graded out of 100 points; to pass the exam, students must meet or exceed an average score of 70%.

A list of topics and suggested books is given below.

### Solids Component

#### *Advanced Strength of Materials*

Topics:

- Castigliano's theorems and the Ritz method applied to bars, trusses, beams, plates and frames
- thick-walled cylinders
- stress transformation and principal values
- stress-based criteria to predict yielding in ductile materials, slip in granular materials, and failure of brittle materials
- stress intensity factors and their use to predict brittle fracture
- S-N curves, the Goodman correlation, and the Minor rule to predict fatigue life using a stress-based approach
- Paris law prediction of fatigue crack growth

Suggested Books and Chapters:

- Norman E. Dowling (2007) *Mechanical Behavior of Materials*, 3rd Edition, Prentice Hall. [Chapters 5–9, 11–13]
- Arthur P. Boresi and Richard J. Schmidt (2003) *Advanced Mechanics of Materials*, 6th Edition, John Wiley & Sons. [Chapters 1–5, 7, 11–16]

### *Continuum Mechanics*

#### Topics:

- basic concepts of linear algebra
- notion of derivative as a linear operator
- divergence theorem
- Eulerian and Lagrangian descriptions of motion
- relationship between strain and motion
- Eulerian and Lagrangian characterizations of rigid body motion
- balance laws
- Cauchy theorem and stress
- work-energy theorem, principle of virtual work
- What are constitutive equations? What is the basic difference between constitutive equations for solids and constitutive equations for fluids?
- Concept of material symmetry. Concept of isotropy.

#### Suggested Books and Chapters:

- Ray M. Bowen (1989) *Introduction to Continuum Mechanics for Engineers*, Plenum Publishing. [Appendix A (no proofs); Chapter 2; Chapter 3 (without jump conditions); Chapter 4 (no proofs concerning material frame indifference and symmetry properties)].
- Morton E. Gurtin (1981) *An Introduction to Continuum Mechanics*, Academic Press. [Chapters 1 & 2 (without proofs); Chapter 3 (the only proofs required concern the characterization of homogeneous deformations and the Reynolds Transport theorem); Chapter 4 & 5; Chapter 6 (no proofs); Chapter 9 (skip the part concerning material frame indifference); Chapter 10 (up to the formulation of the governing equations for the linear elastic BVP)].
- Lawrence E. Malvern (1969) *Introduction to the Mechanics of a Continuous Medium*, Prentice Hall. [Chapter 2 (no proofs); Chapter 3.1–3.3; Chapter 4; Chapter 5.1–5.6; Chapter 6.1–6.3 (reading); Chapter 7.1–7.3].
- A. J. M. Spencer (1992) *Continuum Mechanics*, Dover Publications. [Chapters 1–10].

### *Elasticity*

#### Topics:

- Cartesian tensors
- integral theorems
- strain-displacement relations in a regime of small deformation, infinitesimal rotation tensor, hydrostatic and deviatoric components of stress and strain, principal strains, thermal strains

- stress vector and stress tensor, principal stresses and principal planes.
- strain compatibility equations
- equations of equilibrium
- elastic moduli, constitutive equations of an isotropic linear elastic material, constitutive equations of an isotropic linear thermo-elastic material
- strain energy, principle of virtual work
- the linear elastic boundary value problem, superposition, existence and uniqueness of solutions
- two-dimensional elasticity in Cartesian coordinates, plane strain, plane stress, generalized plane stress, anti-plane strain.
- basic understanding of the assumptions and solution behavior of the following problems:
  - two-dimensional problems of elasticity in cylindrical coordinates – torsion of prismatic cylinders, membrane analogy
  - stress analysis of rotating discs
  - stress analysis of thick-walled cylinders
  - bending of rectangular plates and axisymmetrically loaded circular plates
  - stress analysis of axisymmetric shells

Suggested Books and Chapters:

- Martin H. Sadd (2004) Elasticity: Theory, Applications, and Numerics, Academic Press. [Chapters 1–9]
- Pei Chi Chou and Nicholas J. Pagano (1967) Elasticity: Tensor, Dyadic, and Engineering Approaches, Dover Publications. [all Chapters]

## **Motion Component**

*Advanced Dynamics*

Topics:

- time derivative of a vector
- kinematics in Cartesian, path, cylindrical, and spherical coordinates
- angular velocity and angular acceleration
- velocity and acceleration in a moving reference frame
- particle kinetics, including energy and momentum principles
- rigid body kinematics, including finite rotations (e.g., Euler angles)
- rigid body kinetics, including moments of inertia, and the translational and rotational equations of motion
- analytical mechanics, including generalized coordinates, virtual work, Hamilton's principle, and Lagrange's equations

Suggested Books and Chapters:

- Jerry H. Ginsberg (1998) Advanced Engineering Dynamics, 2nd Edition, Cambridge University Press. [Chapters 2–6]

- Donald T. Greenwood (1988) Principles of Dynamics, 2nd Edition, Prentice-Hall. [Chapters 1–4, 6–8]

### *Linear Vibrations*

Topics:

- What are “linear” vibrations? Why is this a useful and important concept? How do linear vibrations arise in physical problems?
- Finite DOF systems: general form of such systems; natural frequencies and normal modes; frequency response; decomposition using normal modes (i.e., modal analysis).
- Vibrations of continuous systems: formulation of governing equations and simple boundary conditions via Hamilton’s principle for strings, membranes, rods, and beams.
- Natural frequencies and normal modes for continuous systems; orthogonality of the normal modes; frequency response; modal analysis.
- Approximation methods: Rayleigh’s energy principle and the Rayleigh quotient; Rayleigh-Ritz method; assumed modes method and Galerkin projection; relationship to finite element method.

Suggested Books and Chapters:

- Leonard Meirovitch (2000) Fundamentals of Vibrations, McGraw-Hill. [Chapters 1–8]
- Leonard Meirovitch (1997) Principles and Techniques of Vibrations, Prentice Hall. [Chapters 1–4, 7]
- William T. Thomson and Marie Dillon Dahleh (1997) Theory of Vibration with Applications, 5th Edition, Prentice Hall. [Chapters 1–6, 9]

### *Elastic Wave Propagation*

Topics:

- dispersion principles
- unbounded isotropic and anisotropic media
- reflection and refraction, oblique incidence, wave scattering
- surface and subsurface waves, waves in plates, interface waves, layer on a half space, waves in rods, waves in hollow cylinders
- guided waves in multiple layers, and horizontal shear waves, respectively

Suggested Books and Chapters:

- Joseph L. Rose (2014) Ultrasonic Guided Waves in Solid Media, Cambridge University Press.

### **Relevant Mathematics Topics**

#### *Numerical Analysis*

Topics:

- round-off errors, computer arithmetic, convergence, and Taylor series
- solutions to nonlinear algebraic equations in one variable
- interpolation and polynomial approximation
- numerical differentiation and integration and concepts of quadrature
- fundamental ideas for initial value problems for ODEs
- fundamental ideas for solution of linear algebraic systems of equations
- fundamental ideas in approximation theory
- fundamental ideas for boundary value problems for ODEs, such as finite difference and finite element methods.

Suggested Books and Chapters:

- Richard L. Burden and J. Douglas Faires (2004) Numerical Analysis, 8th Edition, Brooks Cole. [Chapters 1–6, 8, 11]
- Steven C. Chapra and Raymond P. Canale (2002) Numerical Methods for Engineers, 4th Edition, McGraw-Hill. [Chapters 3–6, 9, 10, 17, 18, 21–23, 25–27]

### *Variational Calculus*

Topics:

- generalized coordinates
- first variation and generalized forces
- extremum problems
- stationary values of integrals and the Euler-Lagrange equations
- second variation
- basic ideas of the Ritz method

Suggested Books and Chapters:

- Cornelius Lanczos (1986) The Variational Principles of Mechanics, 4th Edition, Dover Publications. [Chapters 1–3]
- Charles Fox (1987) An Introduction to the Calculus of Variations, Dover Publications. [Chapters 1–4]

### *Ordinary Differential Equations*

Topics:

- classification of ODEs
- techniques for first-order equations
- techniques for higher order linear ODEs with constant coefficients
- power series solutions to ODEs

Suggested Books and Chapters:

- Erwin Kreyszig (1998) Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons. [Chapters 1, 2, 4]

- Michael Greenberg (1998) Advanced Engineering Mathematics, 2nd Edition, Prentice Hall. [Chapters 2–4]

### *Partial Differential Equations*

Topics:

- Fourier series, Fourier integrals, and Fourier and Laplace transforms
- classification of PDEs
- diffusion, wave, and Laplace equations: separation of variables solutions

Suggested Books and Chapters:

- Erwin Kreyszig (1998) Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons. [Chapters 10, 11]
- Michael Greenberg (1998) Advanced Engineering Mathematics, 2nd Edition, Prentice Hall. [Chapters 17–20]

### *Linear Algebra*

Topics:

- ideas and concepts behind the solution of systems of linear algebraic equations
- vector spaces, linear dependence, bases
- the eigenvalue problem

Suggested Books and Chapters:

- Erwin Kreyszig (1998) Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons. [Chapters 6, 7]
- Michael Greenberg (1998) Advanced Engineering Mathematics, 2nd Edition, Prentice Hall. [Chapters 8–11]

### *Complex Variables*

Topics:

- functions of a complex variable, analyticity
- complex integration, Cauchy's theorem, the residue theorem
- Taylor series, Laurent series

Suggested Books and Chapters:

- Erwin Kreyszig (1998) Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons. [Chapters 12–15]
- Michael Greenberg (1998) Advanced Engineering Mathematics, 2nd Edition, Prentice Hall. [Chapters 21–24]

## APPENDIX C: QUALIFYING EXAM: DISCIPLINARY COMPONENT IN ELECTROMAGNETISM

### Goals

This exam is to evaluate student's fundamental understanding of electromagnetism. While students are expected to be familiar with the basic laws of static electric and magnetic fields, which may be "coupled" and viewed "independent" of one another, they must be familiar with the basic links of electric and magnetic fields and their unification into the more general framework of Maxwell's equations. In addition to electrostatics, magnetostatics, and electromagnetic wave propagation, a fundamental knowledge of electromagnetic wave interaction with matter is an important element for graduate students in the interdisciplinary ESM Department. Electric and magnetic polarization mechanisms contribute to the basic dielectric and magnetic properties, which are generally considered to be constant. The student should have an appreciation that electromagnetic properties of matter are nonlinear and are dependent on thermal and mechanical stresses. Coupled structural, electromagnetic, and thermal phenomena yield important material properties such as piezoelectricity and magnetostriction. Moreover, the wave-particle nature of electromagnetic radiation is important to its interaction with matter and students are, therefore, expected to understand this wave-particle duality. Also, students must be familiar with the engineering applications of electricity and magnetism in electric circuits and optics.

### Scope

The exam will assess the student's general knowledge in the following areas:

#### Electrostatics

Coulomb's law, E and D fields, Gauss' law, electric potential, dipole, energy, density in an electric field, Gauss' divergence theorem

#### Magnetism

Biot-Savart law, Ampere's law, Stoke's theorem, B and H fields

#### Time-Varying Electromagnetic Fields and Maxwell's Equations

Faraday's law, Maxwell's equations in differential and integral forms, plane wave propagation in different media and at boundaries, gauges and gauge transformation, introduction to transmission lines and waveguides

Material is typically found in :

"*Engineering electromagnetics*" 6<sup>th</sup> edition, (2001), By William H. Hayt, Jr. and John A. Buck, Pub. McGraw Hill

or



“*Classical Electrodynamics*”, 3<sup>rd</sup> edition, 1998, By John D. Jackson, Pub. John Wiley & Sons, Inc.

### Electric Circuits

RLC circuit analysis, impedance and admittance, network theorems and analysis, power dissipation

Material is typically found in:

“*Engineering Circuit Analysis*” by Hayt, Kemmerly. and Durbin

### Wave-Particle Duality of Electromagnetic Radiation and Interaction with Matter

Photon, 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

Material is typically found in:

“*Principles of Electronic Materials and Devices*”, 2nd edition, (2002), by S. O. Kasap, Pub. McGraw Hill

### Optics

*Geometrical optics*: light rays, reflection, refraction, Snell’s law, total internal reflection, lenses, prisms, optical fibers

*Physical optics*: Huygen’s principle and the wave nature of light, interference and interferometry, diffraction, dispersion, attenuation, microscopy

Material is typically found in:

“*Fundamentals of Optics*”, by Francis Jenkins and Harvey E. White, Pub. McGraw Hill

## **Format**

The exam consists of **12 Questions** related to various aspects of electromagnetism.

Two 2 questions are given for each of the defined subject areas:

1) Electric Circuits

2) Wave-Particle Duality of Electromagnetic Radiation and Interaction with Matter

3) Electrostatics

4) Magnetism

5) Time-Varying Electromagnetic Fields

6) Optics

One question must be answered in **EACH** section, (i.e. 6 out of the 12 given for the exam)

## **APPENDIX D: QUALIFYING EXAM: DISCIPLINARY COMPONENT IN NEURAL ENGINEERING SCIENCE**

The core competencies in Neural Engineering Science, upon which the specialty qualifying examination will draw from, will be based upon material covered in the following courses:

- Neural Engineering: Fundamentals Of Interfacing with Brain (ESC 525)
- Molecular and Cellular Neuroscience (Neuro 520)
- Systems Neuroscience (Neuro 521)
- Electromagnetic Fields (E SC 400H)
- Mathematical Methods in Engineering (E MCH 524A)
- Fundamentals of Data Analysis in Neuroscience (ESC 555)

Neural Engineering is the application of quantitative engineering tools to interfacing and understanding the biology of the nervous system. The exam itself is conceptually broken up into 3 sections – a section designed to test fundamental engineering skills, a section to probe basic knowledge of the biology of the nervous system, and a section that tests quantitative problem solving associated with the nervous system. The exam is designed to be completed in less than the allocated 4 hours.

Approximate formats are as follow:

- Engineering Fundamentals: (1.5 hours) Solve 4 of 5 quantitative problems similar to those covered in courses:
  - E MCH 524A Mathematical Methods In Engineering
  - E SC 555 Fundamentals of Data Analysis in Neuroscience
  - E SC 400H Electromagnetic Fields
- Neuronal Fundamentals: (0.5 hours) Answer 4 to 6 short answer questions at level and from topics covered in the courses:
  - Neuro 520 Molecular and Cellular Neuroscience
  - Neuro 521 Systems Neuroscience
  - E SC 525 Neural Engineering: Fundamentals of Interfacing with Brain
- Neural Engineering: (2.0 hours) Answer 3 of 4 quantitative (problem solving) questions. These would typically be drawn from the full range of topics covered in all core qualifying courses mentioned above.

## APPENDIX E: QUALIFYING EXAM: DISCIPLINARY COMPONENT IN MATERIALS

This examination tests the candidate's preparation to pursue Ph.D. level research in the interdisciplinary program of the Department of Engineering Science and Mechanics. As such, the examination accommodates both the broad range and interdisciplinary nature of ESM graduate student and faculty interests while assuring fundamental competence and breadth of understanding. The exam has three components: a written exam, a research paper, and an oral presentation. The candidate must pass each one of these components.

### Syllabus (Written Part)

- The Exam will consist of 5 Topics as summarized in Table 1. The candidate will need to study the Chapters/Sections from the respective Books as indicated in Table 1.
- In the Exam, there will be 8 questions from each Topic: 4 questions with 5 Points each and 4 questions with 10 Points each
- The candidate will need to answer a maximum of 100 Points
- The candidate must answer 40 Points from one of the 5 Topic
- The candidate must not answer more than 25 Points from any of the remaining Topics.
- The candidate must score 70 Points or above to pass the written part of the examination

**Table 1**

Topic	Book	Chapters
Structure	Callister	C2, C3, C4, C12, C14, C16
	Kasap	K1, K2, K3
Characterization	Leng	L1.1, L2.1-2.2, L3.1, L4.1-4.2, L5.1, L6.1, L7.1, L8.1, L9.1, L10.1
Processing	Callister	C5, C9, C11, C13.1-13.3, C15.1-15.4, C15.8-15.17, C15.20-15.24
	Kasap	K1.7, K1.12, K5.5
Properties	Callister	C8, C18, C19
	Kasap	K2.5-2.7
Solid-state physics	Kasap	K3, K4, K5, K6.1-6.10, K6.13-6.15

Kasap. Principles of Electronic Materials and Devices, Safa O. Kasap, 3<sup>rd</sup> Edition, McGraw Hill, 2006.

Callister. Materials Science and Engineering: An Introduction by William D. Callister, 9<sup>th</sup> Edition, McGraw-Hill, 2006.

Leng. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng, 2<sup>nd</sup> Edition, Wiley-VCH, 2013.

## Proposal and Oral Examination

After the candidate has taken the written test, the candidate will be assigned a topic for the research paper and oral presentation. The candidate will be given two weeks to write the paper and submit a copy of their presentation viewgraphs. The candidacy committee will evaluate the research paper and oral presentation. A final recommendation is then made to the faculty at a faculty meeting and the candidate will then be notified as to whether they have passed or failed any of the components and whether there are any other recommendations from the committee.

The written examination is given first and is administered in two parts: A and B.

### Part A

Part A consists of introductory level material dealing with a broad range of materials science and engineering topics: crystal structure, basic principles of quantum mechanics, elementary topics in the electronic properties of materials, elementary topics in the mechanical behavior of materials, elementary principles of thermodynamics and kinetics of materials. It will also assess general knowledge of all materials including conductors, semiconductors, insulators, metals, ceramics and polymers. Thus, part A will assess the student's general knowledge of materials science and engineering. The goal of this examination will be to determine whether the student has a sufficiently broad background to tackle Ph.D. level research. Because materials science and engineering is exceptionally broad in scope and because our students come from an exceptionally broad range of backgrounds, the part A examination will consist of more questions than the candidate is required to answer. The student will be required to answer about half of the examination questions, typically six of twelve questions. The part A examination score will count for 64% of the written exam score. Chapters from several books listed below will be the source of questions for this part of the exam.

This section of the test will, this semester, be based primarily but not exclusively on specific chapters of the following books:

Materials Science and Engineering: An Introduction by William D. Callister, 9<sup>th</sup> Edition, McGraw-Hill, 2006. (Chapters 1-6, 9, 12,14,18)

Principles of Electronic Materials and Devices, S.O. Kasap, 3<sup>rd</sup> ed., McGraw Hill, 2006. (Chapters 1-5)

### Part B

Part B will cover more advanced material and will reflect the student's academic and research interests and will test the student's expertise at the introductory graduate level. Part B examination

topics may include standard fundamental materials science topics such as thermodynamics and kinetics of solids, quantum mechanics, electronic properties of materials, mechanical properties of materials, and analytical techniques in materials science, such as X-ray, crystallography, electron microscopy, or magnetic resonance. Because the Department of Engineering Science and Mechanics provides a uniquely nurturing environment for interdisciplinary research encourages interdisciplinary research Part B examination topics may also include other topics which are not, of themselves, materials science or materials engineering topics but which are relevant to the candidate's research and academic interests. Examples of such topics are solid state electronics and digital signal processing.

The candidate, with consultation of the candidate's thesis advisor will be asked to provide a list of 2 or 3 courses and/or two or three topics suitable for the Part B examination based on the courses they have taken at Penn State or prior expertise. At least one of these topics/courses must, at least broadly, be in engineering science and materials engineering. This list must be provided ***within two weeks of the town meeting***. A few examples may be useful to illustrate the possibilities. Student W requests three examination topics based on courses: X-ray crystallography, engineered thin films, and biological surfaces. Student X requests three part B examination topics: electronic properties of materials, solid state electronics, and digital signal processing. Student Y requests three examination topics: magnetic resonance, quantum mechanics, and digital signal processing. Student Z requests three examination topics: powder metallurgy, characterization of microstructure, process and property modeling As in part A, more questions will be provided than required, typically the student would be required to answer about two thirds of the questions provided in the examination, typically four of six questions. Part B would count 36% towards the total score of the written examination.

The written examination will be prepared by a committee of at least four faculty members of ESM, all of whom are actively engaged in materials research and all of whom are actively supervising graduate students engaged in materials related research. The candidate's thesis advisor will serve on the examination committee but NOT as chair or co-chair. Faculty outside the ESM department will be consulted in the preparation of part B examination questions so that this part of the exam evaluates competency on courses taken by the student or their area of emphasis.

The minimum passing score on the written examination is 70%.

After the candidate has taken the written test, the candidate will be assigned a topic for the research paper and oral presentation. The candidate will be given two weeks to write the paper and submit a copy of their presentation viewgraphs. The candidacy committee will evaluate the research paper and oral presentation. A final recommendation is then made to the faculty at a faculty meeting and the candidate will then be notified as to whether they have passed or failed any of the components and whether there are any other recommendations from the committee.

## APPENDIX F: QUALIFYING EXAM Evaluation Forms

### Engineering Science and Mechanics (ESM) Qualifying Exam Evaluation

Candidate: \_\_\_\_\_

Date: \_\_\_\_\_

Specialty Track: \_\_\_\_\_

Examining Sub-Committee Members:

The Qualifying Exam provides an **early assessment** of the Program Learning Objectives as well as English Competency.

#### Program Learning Objectives Assessment

	Excellent	Very Good	Satisfactory	Unsatisfactory
Candidates will demonstrate an in-depth knowledge of the core theories and methods within one or more sub-specialties in the fields of ESM. The core demonstration will include the application of physics, advanced mathematics and engineering principles to problems in mechanics, materials, bionanotechnology, nanoscience and neuroscience.				
<b>Knowledge: Disciplinary Component and Proposal</b>  <i>Circle one of the four boxes →</i>	The student demonstrates an excellent command of the subject matter that forms the basis for an advanced degree in ESM.	The student shows a very good command of the subject matter that forms the basis for an advanced degree in ESM.	The student is proficient in the subject matter that forms the basis for an advanced degree in ESM.	The student is seriously deficient in the subject matter that forms the basis for an advanced degree in ESM.
Candidates will be able to critically analyze work by others in their field of specialty.				
<b>Critical Thinking:</b>  <b>Background/Literature Review</b>  <i>Circle one of the four boxes →</i>	The literature was critically reviewed and the student demonstrated an excellent understanding of current state of the research topic.	The literature was critically reviewed and the student demonstrated a very good understanding of current state of the research topic.	The literature was reviewed and the student demonstrated an understanding of current state of the research topic.	The literature was not adequately reviewed and the student had a lack of understanding of the current state of the research topic.
Candidates will be able to synthesize theory, literature and experimental results to generate new concepts, designs or hypotheses in ESM.				
<b>Creativity:</b>	The proposed research objective is excellent. The plan is substantively creative and follows	The proposed research objective is very good. The plan is creative and follows naturally from	The proposed research objective is satisfactory. The plan follows naturally from the design or hypothesis.	The proposed research objective and plan are either invalid or significantly lacking.

<b>Proposed Research Objective and Plan</b>  <i>Circle one of the four boxes →</i>	naturally from the design or hypothesis.	the design or hypothesis.		
<b>Candidates will be able to carry out independent and original research studies that address current problems in the multi-disciplinary field of ESM.</b>				
<b>Application:</b>  <b>Proposed Research Plan</b>  <i>Circle one of the four boxes →</i>	The research plan expands upon the literature in a novel way and contains original ideas.	The research plan expands upon the literature and proposes something original.	The research plan incrementally expands upon the literature, and/or may contain flaws.	The research plan simply mimics the literature or is judged unlikely to produce results.
<b>Candidates will be able to convey ideas or arguments in clear, concise, well organized papers and proposals as well as in formal, oral presentations.</b>				
<b>Communication:</b>  <i>Circle one of the four boxes →</i>	The student is able to defend their ideas coherently and with a substantial discussion of the research topic	The student is able to defend their ideas coherently that are critical to the proposed research.	The student is, for the most part, able to defend their ideas that are critical to the proposed research.	The student is unable to defend their ideas that are critical to the proposed research.

Score from Disciplinary Component of the Exam = \_\_\_\_\_ and (Circle One): **Pass** **Fail**

The sub-committee's assessment of the Research Component of the Exam (Circle One): **Pass** **Fail**

Summary Assessment Statement:



## English Competency Assessment

	Excellent	Very Good	Satisfactory	Unsatisfactory
<b>Use of Oral English</b>  <i>Circle one of the four boxes →</i>	The student demonstrates excellent command of the English language.	The student demonstrates a very good command of the English language.	The student demonstrates a satisfactory command of the English language.	The student's ability to communicate is seriously impaired by inadequate oral skills.
<b>Use of Written English</b>  <i>Circle one of the four boxes →</i>	Language clearly conveys meaning to the readers. The language in the document is excellent.	The style and word choice are very good. The use of language facilitates understanding the proposal.	The style is good but with occasional poor word choice. Style could be improved.	The use of English is sufficiently poor to make the text difficult to understand.

The sub-committee's assessment of English Competency: **Pass** ☐

Suggestions for continued improvement:

**Exam Chair Signature** \_\_\_\_\_

**Specialty Examination Board Recommendation** (Circle One): **Pass** **Fail**

Concluding Remark:

**Specialty Examination Chair Signature** \_\_\_\_\_

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