

ENGINEERING SCIENCE AND MECHANICS

Graduate Program Head	Albert Segall
Program Code	EMCH (M.Eng.); ESMCH (Ph.D., M.S.)
Campus(es)	University Park (Ph.D., M.S., M.Eng.)
Degrees Conferred	Doctor of Philosophy (Ph.D.) Master of Science (M.S.) Master of Engineering (M.Eng.) in Engineering Mechanics Integrated B.S. in Engineering Science and M.S. in Engineering Science and Mechanics Joint M.D./Ph.D. with the College of Medicine
The Graduate Faculty	View (https://secure.gradsch.psu.edu/gpms/?searchType=fac&prog=ESMCH)

Opportunities for graduate studies are available in interdisciplinary and multidisciplinary research areas including:

- Multiscale, multiphysical computational modeling and simulation
- Data Science AI, machine learning
- Brain Science, neural engineering, neuroethics
- Structural and health monitoring
- Advanced materials
 - elastodynamic metamaterials
 - electronic materials
 - twisted 2D materials
 - bioengineered materials
- Materials characterization
 - In-situ microscopy in extreme environments
 - Ultrasonic nondestructive evaluation
- Additive manufacturing
- Micro and nanomechanics
- Biomechanics and mechanobiology
- Quantum computation and information science
- Optoelectronics, nanophotonics, and lasers
- Dynamic systems, acoustics, and vibrations
- Emerging manufacturing process for materials, tissues, and devices
- Bionanoscience, biomedical electronics and devices
- Smart sensors
 - Flexible and stretchable biosensors
 - Label-free biosensors
 - Quantum sensors

Admission Requirements

Applicants apply for admission to the program via the Graduate School application for admission (<https://gradschool.psu.edu/graduate-admissions/how-to-apply/>). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300 Admissions Policies (<https://gradschool.psu.edu/graduate-education-policies/>).

Applicants who hold a baccalaureate degree in engineering, the sciences, mathematics, engineering science, and materials who present at least a 3.00 grade-point average will be considered for admission. Exceptions to the minimum 3.00 grade-point average may be made for students with special backgrounds, abilities, and interests at the discretion of the program. Applicants will be accepted up to the number of places available for new students. GRE scores are not required for admission.

The language of instruction at Penn State is English. English proficiency test scores (TOEFL/IELTS) may be required for international applicants. See GCAC-305 Admission Requirements for International Students (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-300/gcac-305-admission-requirements-international-students/>) for more information.

Degree Requirements

Master of Engineering (M.Eng.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-700 Professional Degree Policies (<https://gradschool.psu.edu/graduate-education-policies/>).

At least 31 credits at the 400, 500, or 800 must be earned, with at least 18 at the 500 or 800 level, and at least 6 at the 500 level. Of these, 22 must be from lecture/laboratory courses approved by the department.

Code	Title	Credits
Required Courses		
ESC 514	Engineering Science and Mechanics Seminar	1
or EMCH 514	Engineering Science and Mechanics Seminar	
Select 3 credits in each of the following areas:		12
Analysis		
Fields		
Motion		
Materials Performance/Reliability or Materials Processing/ Structure/Characterization		
Select 3 additional credits from any one of the four categories above		3
Electives		
Select 12 elective credits		12
Culminating Experience		
ESC 596	Individual Studies	3
or EMCH 596	Individual Studies	
Total Credits		31

A scholarly written report on a developmental study involving at least one area represented in the course work must be written while enrolled in either ESC 596 or EMCH 596. This scholarly paper should reflect the high quality of research required to meet the Engineering Science and Mechanics M.Eng. degree standards, as determined by the ESM Graduate Officer and the ESM Graduate Curriculum Committee.

A 3.0 minimum grade point average is required to maintain good academic standing and for graduation.

Master of Science (M.S.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (<https://gradschool.psu.edu/graduate-education-policies/>)

Thesis Track

At least 32 credits at the 400, 500, 600, or 800 level must be earned, with at least 18 credits at the 500 and 600 levels combined, and 24 credits must be from 400- and 500-level lecture/laboratory courses approved by the department. No more than 6 credits may be earned from 400-level courses.

Code	Title	Credits
Required Courses		
Select 3 credits in the area of Mathematical Methods in Engineering (EMCH 524A, or an equivalent or more advanced course)		3
Select 3 credits in the area of Mechanics		3
Select 3 credits in the area of Materials		3
Select 3 credits in the area of Engineering Science		3
EMCH 514	Engineering Science and Mechanics Seminar	2
or ESC 514	Engineering Science and Mechanics Seminar	
Electives		12
Culminating Experience		
Select 6 credits of thesis research:		6
EMCH 600	Thesis Research	
EMCH 610	Thesis Research Off Campus	
ESC 600	Thesis Research	
ESC 610	Thesis Research Off Campus	
Total Credits		32

A thesis is required and at least 6 credits of thesis research must be included in the student's program of study. The thesis must be a well-organized account of research undertaken by the student and must show initiative and originality. The thesis must be accepted by the advisers and/or committee members, the head of the graduate program, and the Graduate School, and the student must pass a thesis defense.

A 3.0 minimum grade-point average is required to maintain good academic standing and for graduation.

Non-Thesis Track

At least 32 credits at the 400, 500, 600, or 800 level must be earned, with at least 18 credits at the 500 level, and 27 credits must be from 400- and 500-level lecture/laboratory courses approved by the department. No more than 6 credits may be earned from 400-level courses.

Code	Title	Credits
Required Courses		
EMCH 524A	Mathematical Methods in Engineering (or an equivalent or more advanced course)	3
EMCH 514	Engineering Science and Mechanics Seminar	2
or ESC 514	Engineering Science and Mechanics Seminar	
Electives		24
Culminating Experience		
ESC 596	Individual Studies	3
or EMCH 596	Individual Studies	
Total Credits		32

The student is required to complete an independent research experience resulting in a scholarly paper, for which 3 credits of ESC 596 or EMCH 596 will be earned. This scholarly paper should reflect the high quality of research required to meet the Engineering Science and Mechanics M.S.

degree standards, as determined by the ESM Graduate Officer and the ESM Graduate Curriculum Committee.

A 3.0 minimum grade-point average is required to maintain good academic standing and for graduation.

Doctor of Philosophy (Ph.D.)

Requirements listed here are in addition to Graduate Council policies listed under GCAC-600 Research Degree Policies. (<https://gradschool.psu.edu/graduate-education-policies/>)

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

The minimum number of course credits required for students entering the Ph.D. program with a baccalaureate degree:

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 (EMCH 514/ESC 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 (EMCH 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 (a list of the courses in these categories is provided in the Graduate Programs Guide of the Engineering Science and Mechanics Department).

A minimum of 15 course credits must be in the major (courses with EMCH and/or ESC prefixes).

Twelve credits of letter grade Thesis Research with EMCH 600/ESC 600 designation are required. Students are allowed to register for EMCH 600/ESC 600 credits beyond the 12 required, but these credits will receive a grade of "R" if successfully completed. Students are allowed to register for EMCH 600/ESC 600 credits only before passing the Comprehensive Examination, after which they must register for EMCH 601/ESC 601 for 0 credits.

The student must demonstrate English competency, and pass a qualifying examination, a comprehensive examination, and 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. The dissertation must be accepted by the Ph.D. committee, the head of the graduate program, and the Graduate School. A minimum grade-point average of 3.00 for work done at the University is required for admission to the qualifying examination, the comprehensive examination, and the final oral examination, and for graduation. Graduate Council requires the student to have a high level of competence in the reading, writing, listening, and speaking of English before the Comprehensive Examination is scheduled.

Integrated Undergrad-Grad Programs

Integrated B.S. in Engineering Science And M.S. in Engineering Science and Mechanics

This Integrated Undergraduate/Graduate (IUG) degree program combines the B.S. in Engineering Science with the M.S. in Engineering offered at the following campuses:

Undergraduate Degree

- University Park

Graduate Degree

- University Park

Requirements listed here are in addition to requirements listed in GCAC-210 Integrated Undergraduate-Graduate (IUG) Degree Programs (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-210-integrated-undergraduate-graduate-degree-programs/>).

The flexibility and strength in fundamentals of the Engineering Science curriculum provides an opportunity for Engineering Science undergraduate students to participate in the ESM Integrated Undergraduate Graduate (IUG) program. The IUG program promotes the interchange of ideas across all branches of the scientific and engineering disciplines from both a theoretical and experimental perspective. Students in the integrated degree program are expected to pursue interdisciplinary studies in areas that encompass nano- and bionanotechnology, advanced materials, electromagnetic, mechanics, microelectronics, nanoelectronics and bioelectronics, neural engineering, photonics and photovoltaics (among others) and they are expected to embrace multidisciplinary perspectives across departmental, College, and University boundaries.

Applicants apply for admission to the program via the Graduate School application for admission (<https://gradschool.psu.edu/graduate-admissions/how-to-apply/>). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300 Admissions Policies (<https://gradschool.psu.edu/graduate-education-policies/>).

Application for IUG status may be made in the fifth or subsequent semesters. Students must apply to the program via the Graduate School application for admission (<http://www.gradschool.psu.edu/prospective-students/how-to-apply/>), and must meet all the admission requirements of the Graduate School and the Engineering Science and Mechanics graduate program for the Master of Science degree. Before applying to the Graduate School, students must have completed entrance to their undergraduate major and have completed no less than 60 credits. Students must be admitted no later than the end of the second week of the semester preceding the semester of expected conferral of the undergraduate degree. Transfer students must have completed at least 15 credits at Penn State to enroll in an IUG.

In consultation with an adviser, students must prepare a plan of study appropriate to this integrated program, and must present their plan of study to the head of the graduate program or the appropriate committee overseeing the integrated program prior to being admitted to the program. The plan should cover the entire time period of the integrated program, and it should be reviewed periodically with an adviser as the student advances through the program.

Students must fulfill all requirements for each degree in order to be awarded that degree, subject to the double-counting of credits as outlined below. Degree requirements for the B.S. in Engineering Science are listed in the Undergraduate Bulletin (<https://bulletins.psu.edu/undergraduate/>). Degree requirements for the M.S. degree are listed on the Degree Requirements tab. If students accepted into the IUG program are unable to complete the M.S. degree, they are still eligible to receive

their undergraduate degree if all the undergraduate degree requirements have been satisfied.

Students must sequence their courses so all undergraduate degree requirements are fulfilled before taking courses to count solely towards the graduate degree. Students are expected to complete the undergraduate degree requirements within the typical time to degree for the undergraduate major. 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.

Code	Title	Credits
Courses Eligible to Double Count for Both Degrees		
EMCH 400	Advanced Strength of Materials and Design	3
ESC 419	Electronic Properties and Applications of Materials	3
EMCH 407	Computer Methods in Engineering Design	3
ESC 404	Analysis in Engineering Science	3
EMCH 524A	Mathematical Methods in Engineering	3
ESC 501	Solar Cell Devices	3
ESC 551	High Power Energy Storage	3

Up to 12 credits may be double-counted towards the degree requirements for both the graduate and undergraduate degrees; a minimum of 50% of the double-counted courses must be at the 500 or 800 level. Independent study courses, the graduate thesis, and credits associated with the culminating experience for the graduate degree cannot be double-counted.

Joint Degrees

Joint M.D./Ph.D. with the College of Medicine

Requirements listed here are in addition to requirements listed in GCAC-211 Joint Degree Programs (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-200/gcac-211-joint-degree-programs/>).

Admission 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. 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 at the discretion of the program 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 (<http://www.gradschool.psu.edu/prospective-students/how-to-apply/>) for admission to the graduate program. Applicants holding undergraduate degrees in engineering, the mathematical sciences, mathematics, engineering science, and materials science and engineering who present a minimum 3.5 grade-point average will be considered for admission. Exceptions to the minimum 3.5 grade-point average may be made at the discretion of the program for students with special backgrounds, abilities, and interests. Applicants will be accepted up to the number of places available for new students.

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

Degree Requirements

The Joint M.D./Ph.D. Program in Engineering Science and Mechanics (M.D./Ph.D., ESMCH) will form the basis for an interdisciplinary, transformational program that will educate a new generation of Physician Engineering Scientists, working at the frontiers of clinical and translational research. This Joint Degree Program responds to the national call to expedite the incorporation of clinical and translational research into improved healthcare.

Students in the Joint M.D./Ph.D. Program in Engineering Science and Mechanics will complete 4 years of medical studies (designated years M1 through M4) at 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 M2. After successfully completing 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 be admitted to the Ph.D. program in Engineering Science and Mechanics.

Students will complete all degree requirements for the Ph.D. Degree in Engineering Science and Mechanics, including SARI (Scholarship and Research Integrity) training for the Responsible Conduct of Research (RCR) that must be met by students admitted to the program with either a baccalaureate or a master's degree, with the following exceptions:

- 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 toward graduate course credit for the Ph.D. degree; and,
- students admitted to the program with a master's degree will be allowed to double count 7 professional credits toward graduate course credit for the Ph.D. degree.

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 (ESC 600/EMCH 610) toward professional credits for the M.D. degree; and,
- master's degree holders will be allowed to double count 5 research credits (ESC 600/EMCH 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. 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).

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.

Minor

A graduate minor is available in any approved graduate major or dual-title program. The default requirements for a graduate minor are stated in Graduate Council policies listed under GCAC-600 Research Degree Policies (<https://gradschool.psu.edu/graduate-education-policies/>) and GCAC-700 Professional Degree Policies (<https://gradschool.psu.edu/graduate-education-policies/>), depending on the type of degree the student is pursuing:

- GCAC-611 Minor - Research Doctorate (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-611-minor-research-doctorate/>)
- GCAC-641 Minor - Research Master's (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-600/gcac-641-minor-research-masters/>)
- GCAC-709 Minor - Professional Doctorate (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-700/gcac-709-professional-doctoral-minor/>)
- GCAC-741 Minor - Professional Master's (<https://gradschool.psu.edu/graduate-education-policies/gcac/gcac-700/gcac-741-masters-minor-professional/>)

Student Aid

Graduate assistantships available to students in this program and other forms of student aid are described in the Tuition & Funding (<https://gradschool.psu.edu/graduate-funding/>) section of The Graduate School's website. Students on graduate assistantships must adhere to the course load limits (<https://gradschool.psu.edu/graduate-education-policies/gsad/gsad-900/gsad-901-graduate-assistants/>) set by The Graduate School.

Research and Teaching Assistantships (half time) are granted to a majority of graduate students in good academic standing. Financial supported is ordinarily limited to three semesters for full-time master's degree students, and six semesters for full-time Ph.D. students.

In addition to the fellowships, traineeships, graduate assistantships, or other forms of financial aid described in the link above, ESM has a number of scholarships that may provide graduate support. Students who wish to request consideration for these funds should notify the ESM Coordinator for Alumni, Development and Advancement in 212 Earth & Engineering Science Building.

Theodore Holden Thomas Jr., Memorial Scholarship

To provide financial assistance to undergraduate or graduate students who display outstanding ability and have enrolled in the Department of Engineering Science and Mechanics.

Sabih and Guler Hayek Graduate Scholarship in Engineering Science and Mechanics

To provide recognition and financial assistance to outstanding graduate students enrolled or planning to enroll in the Department of Engineering Science and Mechanics.

Dr. Richard Llorens Graduate Award in Engineering Science and Mechanics

To provide recognition and financial assistance to graduate students pursuing a degree in Engineering Science and Mechanics who have achieved academic excellence.

Richard P. McNitt Scholarship in Engineering Science and Mechanics

To provide financial assistance to undergraduate or graduate students enrolled in the Department of Engineering Science and Mechanics who have achieved superior academic records or who manifest promise of outstanding academic success.

DR. JOHN T. FRASIER GRADUATE FELLOWSHIP

To recruit and recognize outstanding students enrolled in a graduate degree offered by the Department of Engineering Science and Mechanics.

DEPARTMENT OF ENGINEERING SCIENCE AND MECHANICS GENERAL SCHOLARSHIP

To provide recognition and financial assistance to outstanding graduate and undergraduate students enrolled or planning to enroll in the Department of Engineering Science and Mechanics.

MATTHEW GEORGE WORKMAN SCHOLARSHIP IN THE DEPARTMENT OF ENGINEERING SCIENCE AND MECHANICS IN THE COLLEGE OF ENGINEERING

To provide recognition and financial assistance to students enrolled in the Engineering Science, Engineering Mechanics, or Engineering Science and Mechanics degree programs in the College of Engineering at Penn State University Park.

Dale and Jeanne Mosier Fund for Excellence in Engineering Science and Mechanics

Robert A. Sebrosky Graduate Fellowship in Engineering Science and Mechanics

Courses

Graduate courses carry numbers from 500 to 699 and 800 to 899. Advanced undergraduate courses numbered between 400 and 499 may be used to meet some graduate degree requirements when taken by graduate students. Courses below the 400 level may not. A graduate student may register for or audit these courses in order to make up deficiencies or to fill in gaps in previous education but not to meet requirements for an advanced degree.

Engineering Mechanics (EMCH) Course List (<https://bulletins.psu.edu/university-course-descriptions/graduate/emch/>)

Learning Outcomes

Master of Science (M.S.)

1. **KNOW:** Demonstrate a mastery of core principles and methods in mechanics, materials, and engineering science.
2. **APPLY/CREATE:** Apply engineering problem formulation, planning, organization and implementation of appropriate methods of analysis and solutions.

3. **COMMUNICATE:** Effectively communicate technical knowledge, including ideas, designs, data analysis, findings, or decision justification in written, graphical and oral presentation formats.
4. **THINK:** Critically and creatively conceptualize and evaluate engineering problem formulations, analyses and solutions.
5. **TEAMWORK:** Collaborate in a collegial and ethical manner with other professionals within their field and with diverse scientific and technical backgrounds.
6. **PROFESSIONAL PRACTICE:** Demonstrate a knowledge and the ability to practice the professional standards of engineering and professional behavior.

Doctor of Philosophy (Ph.D.)

1. **KNOW:** 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.
2. **APPLY/CREATE:** Graduates will be able to synthesize theory, literature and experimental results to generate new concepts, designs or hypotheses in engineering science and mechanics.
3. **APPLY/CREATE:** 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.
4. **COMMUNICATE:** Graduates will be able to convey ideas or arguments in clear, concise, well organized papers and proposals as well as in formal, oral presentations.
5. **THINK:** Graduates will be able to critically analyze work by others in their field of specialty.
6. **PROFESSIONAL PRACTICE:** 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.

Contact

Campus	University Park
Graduate Program Head	Albert Eliot Segall
Director of Graduate Studies (DGS) or Professor-in-Charge (PIC)	Albert Eliot Segall
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Program Website	View (http://www.esm.psu.edu/)