ENGINEERING SCIENCE AND MECHANICS

Graduate Program Head
Judith Todd

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/index.cfm?searchType=fac&prog=ESMCH)

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;
- Failure analysis;
- Lithography;
- Microelectromechanical systems (MEMS) and microoptoelectromechanical systems (MOEMS);
- Micromechanics;
- Molecular beam epitaxy;
- Non-destructive evaluation and testing;
- Numerical methods;
- Photovoltaic materials and devices;
- Nanotechnology and nanobiotechnology;
- Properties of materials;
- Shock, vibration acoustics and nonlinear dynamics;
- Structural health monitoring;
- Structural mechanics; and
- Wave-material interactions.

Admission Requirements
Applicants apply for admission to the program via the Graduate School application for admission (http://gradschool.psu.edu/prospective-students/how-to-apply). Requirements listed here are in addition to Graduate Council policies listed under GCAC-300 Admissions Policies (http://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.

Scores from the Graduate Record Examination (GRE) are required for admission. At the discretion of the Graduate Officer, a student may be granted provisional admission (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-300/provisional-admission) pending receipt of acceptable GRE scores.

Degree Requirements

Master of Engineering (M.Eng.)
Requirements listed here are in addition to Graduate Council policies listed under GCAC-700 Professional Degree Policies (http://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.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC 514</td>
<td>Engineering Science and Mechanics Seminar</td>
<td>1</td>
</tr>
<tr>
<td>or EMCH 514</td>
<td>Engineering Science and Mechanics Seminar</td>
<td>1</td>
</tr>
</tbody>
</table>

Select 3 credits in each of the following areas:

- Analysis
- Fields
- Motion
- Materials Performance/Reliability or Materials Processing/Structure/Characterization

Select 3 additional credits from any one of the four categories above

Electives

Select 12 elective credits

Culminating Experience

ESC 596 | Individual Studies | 3       |
| or EMCH 596 | Individual Studies | 3       |

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. (http://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.

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

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.

<table>
<thead>
<tr>
<th>Code</th>
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<th>Credits</th>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>Required Courses</strong></td>
<td></td>
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<tr>
<td></td>
<td>EMCH 524A Mathematical Methods in Engineering</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(or an equivalent or more advanced course)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EMCH 514 Engineering Science and Mechanics</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Seminar</td>
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<tr>
<td></td>
<td>or ESC 514 Engineering Science and Mechanics</td>
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<tr>
<td></td>
<td>Seminar</td>
<td></td>
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<tr>
<td></td>
<td>Electives</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td><strong>Culminating Experience</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ESC 596 Individual Studies</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>or EMCH 596 Individual Studies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total Credits</td>
<td>32</td>
</tr>
</tbody>
</table>

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. (http://gradschool.psu.edu/graduate-education-policies)

Students may enter the Ph.D. program after completing an M.S. degree or directly from the B.S. degree. The student must have completed an appropriate baccalaureate or master’s degree prior to admission. In addition:

- at least 18 credits must be earned in 400- and 500-level lecture/laboratory courses approved by the department; and,
- 3 credits of a graduate seminar (EMCH 514 or ESC 514) must be earned beyond the master’s degree requirements.

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.

**Integrated Undergrad-Grad Programs**

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

Requirements listed here are in addition to requirements listed in GCAC-210 Integrated Undergraduate-Graduate (IUG) Degree Programs (http://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.

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. Students must be admitted to the IUG program no later than the end of the second week of the semester preceding the semester of expected conferral of the undergraduate degree. Students must be admitted to the program prior to taking the first course they intend to count towards the graduate degree.

In consultation with an adviser, students must prepare a plan of study appropriate to this integrated program, and must present their plan of study in person 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.

To earn the Master of Science degree in Engineering Science and Mechanics, students in the IUG program must complete all of the degree requirements for the M.S. degree. 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.

Scores from the Graduate Record Examination (GRE) are required for admission. At the discretion of the Graduate Office, a student may be granted provisional admission (http://gradschool.psu.edu/graduate-education-policies/gcac/gcac-300/provisional-admission) pending receipt of acceptable GRE scores.

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.

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 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:

- students admitted to the program with a baccalaureate degree will be allowed to double count 14 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.

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**Courses Eligible to Double Count for Both Degrees**

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<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>EMCH 400</td>
<td>Advanced Strength of Materials and Design</td>
<td>3</td>
</tr>
<tr>
<td>ESC 419</td>
<td>Electronic Properties and Applications of Materials</td>
<td>3</td>
</tr>
<tr>
<td>EMCH 407</td>
<td>Computer Methods in Engineering Design</td>
<td>3</td>
</tr>
<tr>
<td>ESC 404</td>
<td>Analysis in Engineering Science</td>
<td>3</td>
</tr>
<tr>
<td>EMCH 524A</td>
<td>Mathematical Methods in Engineering</td>
<td>3</td>
</tr>
<tr>
<td>ESC 501</td>
<td>Solar Cell Devices</td>
<td>3</td>
</tr>
<tr>
<td>ESC 551</td>
<td>High Power Energy Storage</td>
<td>3</td>
</tr>
</tbody>
</table>

At least 6 of the double-counted credits must be at the 500-level. The graduate thesis or other graduate culminating/capstone experience (including any associated credits and/or deliverables) may not be double counted towards any other degree.

**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 (http://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.

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:

- students admitted to the program with a baccalaureate degree will be allowed to double count 14 professional credits toward graduate course credit 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.
Student Aid

Graduate assistantships available to students in this program and other forms of student aid are described in the Tuition & Funding (http://gradschool.psu.edu/graduate-funding) section of The Graduate School’s website. Students on graduate assistantships must adhere to the course load limits (http://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, the following awards typically have been available to graduate students in this program.

Theodore Holden Thomas Jr., Memorial Scholarship
Available to undergraduate or graduate students who display outstanding ability and have enrolled in the Department of Engineering Science and Mechanics. Apply to the Department of Engineering Science and Mechanics, 212 Earth-Engineering Sciences Building. Deadline is February 1.

Sabih and Guler Hayek Graduate Scholarship in Engineering Science and Mechanics
Provides recognition and financial assistance to outstanding graduate students enrolled or planning to enroll in the Department of Engineering Science and Mechanics, 211 Earth-Engineering Sciences Building. Deadline is February 1.

Dr. Richard Llorens Graduate Award in Engineering Science and Mechanics
Provides recognition and financial assistance to graduate students pursuing a degree in Engineering Science and Mechanics who have achieved academic excellence. Apply to the Department of Engineering Science and Mechanics, 211 Earth-Engineering Sciences Building. Deadline is February 1.

Richard P. McNitt Scholarship in Engineering Science and Mechanics
Available 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. Apply to the Department of Engineering Science and Mechanics, 212 Earth-Engineering Sciences Building. Deadline is February 1.

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.