Mechanical Engineering (MEEN)

Chairperson: John Borg, Ph.D., P.E.
Mechanical Engineering Graduate Programs website (http://www.marquette.edu/engineering/mechanical/grad.shtml)

Degrees Offered
Master of Science, Master of Engineering; Doctor of Philosophy

Mission Statement
We immerse individuals in an active environment to cultivate broadly educated mechanical engineers who balance theory with practice for advancing knowledge, solving problems and serving society.

Program Description
The Department of Mechanical Engineering offers two master’s programs and a doctoral program. Course work and research in the department's programs may involve the broad fundamentals of mechanical engineering or may concentrate on one or more of the following fields: energy systems, manufacturing and materials systems, and mechanical systems. In these fields, engineering principles are applied not only to traditional equipment and methods but also to modern and emerging technologies. Typically, the engineering course work and research are augmented by laboratory studies. Although the study of advanced engineering mathematics and, often, basic science is necessary in all programs of study, the selection of subjects may vary depending upon the field of specialization and the student's professional objectives.

Prerequisites for Admission
Adequate preparation in engineering, mathematics and science is required. If an applicant does not have an adequate undergraduate background, some remedial studies may be necessary, depending upon the graduate field of specialization the applicant selects.

Application Requirements
Applicants must submit, directly to the Graduate School:

1. A completed application form and fee online (http://marquette.edu/grad/future_apply.shtml).
2. Copies of all college/university transcripts except Marquette.*
3. Three letters of recommendation.
4. (For doctoral applicants only) a brief statement of purpose and copies of any published work, including master’s thesis and essays.
5. (For international applicants only) a TOEFL score or other acceptable proof of English proficiency.
6. GRE scores (General Test only). Scores from the GRE exam are a requirement of admission for all students in the master's, doctoral, and accelerated degree programs.

* Upon admission, final official transcripts from all previously attended colleges/universities, with certified English translations if original language is not English, must be submitted to the Graduate School within the first five weeks of the term of admission or a hold preventing registration for future terms will be placed on the student’s record.

Mechanical Engineering Master of Science (M.S.) Requirements

Specializations: Energy Systems, Manufacturing and Materials Systems, Mechanical Systems

Upon enrolling in the master of science program in mechanical engineering, a student selects one of three areas of specialization: energy systems, manufacturing and materials systems, or mechanical systems. During the first term, a curriculum, along with a research program, is designed with an academic adviser which is specific to the goals of the individual student. The program includes course work in engineering, mathematics and science with the following requirements:

- A minimum of 24 credit hours of course work.
- A minimum of 3 credit hours of an approved math course (MEEN 6101 Advanced Engineering Analysis 1, MEEN 6102 Advanced Engineering Analysis 2, MEEN 6103 Approximate Methods in Engineering Analysis), or equivalent. An equivalent math requirement from another department must be approved by the student's adviser and the director of graduate studies.
- A minimum of one half of the total course work must be at the 6000 level.
- A minimum of one half of the total course work must be taken from the Department of Mechanical Engineering. No more than 12 credit hours may be taken outside the Department of Mechanical Engineering and these courses must be approved by the student's adviser and the director of graduate studies.
- At most, a maximum of 3 credit hours of an Independent Study course may be included in the course work total.
• Six (6) credit hours of thesis work, completion of an oral thesis defense/comprehensive exam and submission of an approved thesis.
• Continuous participation in the departmental graduate seminar series (MEEN 6960 Seminar in Mechanical Engineering).
• Successful acceptance of a conference proceeding or refereed journal article.
• A maximum of 6 credit hours of graduate-level credit from other approved institutions may be accepted toward the requirement of the degree as long as requirements are met, and prior approval must be received from the student’s adviser and director of graduate studies.

Specialization Requirements

Energy Systems

The energy systems specialization typically entails advanced study of (a) thermodynamics, fluid mechanics, heat and mass transfer and combustion; (b) the application of these principles to phenomena and devices which constitute energy-conversion systems; and (c) the analysis, simulation and design of such systems as well as plants; e.g., chemical, metallurgical, food, etc., which are energy-intensive. Current research topics include: plant optimization, cogeneration systems, fluid mechanics and heat transfer in surface mount technology, engine emissions/process effluents and jet engine propulsion systems, energy dispersive materials, and soot modeling.

Required math course:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>MEEN 6101</td>
<td>Advanced Engineering Analysis 1</td>
</tr>
<tr>
<td>or MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
</tr>
<tr>
<td>or MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
</tbody>
</table>

Required specialization courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 5350</td>
<td>Transport Phenomena</td>
</tr>
<tr>
<td>MEEN 5360</td>
<td>Intermediate Thermodynamics</td>
</tr>
</tbody>
</table>

Additional requirements:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 6960</td>
<td>Seminar in Mechanical Engineering (taken every term)</td>
</tr>
<tr>
<td>MEEN 6999</td>
<td>Master's Thesis</td>
</tr>
</tbody>
</table>

Additional course work chosen from the following:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 5260</td>
<td>Introduction to Continuum Mechanics</td>
</tr>
<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Method</td>
</tr>
<tr>
<td>MEEN 5310</td>
<td>Combustion: Thermochemistry, Kinetics and Applications</td>
</tr>
<tr>
<td>MEEN 5325</td>
<td>Intermediate Fluid Mechanics</td>
</tr>
<tr>
<td>MEEN 5410</td>
<td>Experimental Design</td>
</tr>
<tr>
<td>MEEN 5931</td>
<td>Topics in Mechanical Engineering</td>
</tr>
<tr>
<td>MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
</tr>
<tr>
<td>MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
<tr>
<td>MEEN 6260</td>
<td>Multiscale Material Modeling</td>
</tr>
<tr>
<td>MEEN 6310</td>
<td>Advanced Fluid Mechanics</td>
</tr>
<tr>
<td>MEEN 6320</td>
<td>Turbulence</td>
</tr>
<tr>
<td>MEEN 6330</td>
<td>Statistical Thermodynamics</td>
</tr>
<tr>
<td>MEEN 6340</td>
<td>Thermal Radiation Heat Transfer</td>
</tr>
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<td>MEEN 6350</td>
<td>Convective Heat and Mass Transfer</td>
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<td>MEEN 6931</td>
<td>Topics in Mechanical Engineering</td>
</tr>
<tr>
<td>MEEN 6995</td>
<td>Independent Study in Mechanical Engineering</td>
</tr>
</tbody>
</table>

Total Credit Hours 30

Manufacturing and Materials Systems

The manufacturing and materials systems specialization typically entails advanced study in (a) evaluation of materials and their behavior; (b) processes for changing material shape and properties; (c) approaches to economizing complex systems; (d) material-man-machine interfaces; and (e) analysis of the manufacturing complex. Normally, each of these multi-disciplinary areas requires certain core courses along with specialized studies, which may include advanced courses in other engineering disciplines, courses in mathematics and statistics and/or courses in business administration. Current research topics include: cellular manufacturing, polishing and mass finishing processes, flexible assembly, robotic systems, production integration, ergonomics, reliability/quality estimation, human performance and safety evaluation and materials forming and joining processes.

Required math course:

<table>
<thead>
<tr>
<th>Course</th>
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</tr>
</thead>
<tbody>
<tr>
<td>MEEN 6101</td>
<td>Advanced Engineering Analysis 1</td>
</tr>
</tbody>
</table>
Mechanical Systems

The mechanical systems specialization typically entails advanced study of (a) mechanical system design and analysis; and (b) modeling, simulation, and control. Mechanical design and analysis focuses on the use of physical and mathematical principles to understand the behavior of mechanical systems. It includes computer-aided optimal design, such as the design of multi-body, multi-degree-of-freedom mechanical systems. Modeling, simulation and control involve the study of theoretical mechanics in conjunction with computational applications including advanced dynamics, kinematics and stress analysis. Other applications include the modeling and control of manufacturing processes, including robotics and automated deformation processing. Current research areas include: composite and polymeric materials, control in automated assembly, design of compliant machine mechanisms, metal cutting/forming mechanics, finite element methods and multiscale material modeling.

Required math course:

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<tbody>
<tr>
<td>MEEN 6101</td>
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<tr>
<td>or MEEN 6102</td>
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Required specialization courses:

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<tbody>
<tr>
<td>MEEN 5220</td>
<td>Intermediate Dynamics</td>
</tr>
<tr>
<td>MEEN 5230</td>
<td>Intermediate Mechanics of Materials</td>
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</tbody>
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Additional requirements:

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<td>Independent Study in Mechanical Engineering</td>
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</table>

Total Credit Hours 30
<table>
<thead>
<tr>
<th>Course Code</th>
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</tr>
</thead>
<tbody>
<tr>
<td>MEEN 5240</td>
<td>Polymers and Polymer Composites</td>
</tr>
<tr>
<td>MEEN 5245</td>
<td>Fatigue and Fracture Mechanics</td>
</tr>
<tr>
<td>MEEN 5250</td>
<td>Design of Machine Elements 2</td>
</tr>
<tr>
<td>MEEN 5260</td>
<td>Introduction to Continuum Mechanics</td>
</tr>
<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Method</td>
</tr>
<tr>
<td>MEEN 5270</td>
<td>Physical Systems Modeling</td>
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<td>MEEN 5275</td>
<td>Mechatronics</td>
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<td>Experimental Design</td>
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<td>Failure Analysis</td>
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<td>MEEN 5450</td>
<td>Mechanical Behavior of Materials</td>
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<td>MEEN 5570</td>
<td>Biomaterials Science and Engineering</td>
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<td>Topics in Mechanical Engineering</td>
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<td>Advanced Engineering Analysis 2</td>
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<td>MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
<tr>
<td>MEEN 6220</td>
<td>Advanced Dynamics</td>
</tr>
<tr>
<td>MEEN 6225</td>
<td>Advanced Vibrations</td>
</tr>
<tr>
<td>MEEN 6230</td>
<td>Advanced Mechanics of Materials</td>
</tr>
<tr>
<td>MEEN 6240</td>
<td>Composite Materials</td>
</tr>
<tr>
<td>MEEN 6250</td>
<td>Industrial Robotics</td>
</tr>
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<td>MEEN 6260</td>
<td>Multiscale Material Modeling</td>
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**Total Credit Hours** 30

**Master’s Learning Outcomes**

1. Apply knowledge of specialized mechanical engineering concepts in engineering analysis and design in a chosen area of specialization.
2. Effectively communicate ideas on design and analysis to peers, clients and customers.
3. Conduct guided research in a chosen area of specialization.

**Accelerated Bachelor’s–Master’s Degree Program**

The accelerated program enables students to earn both a master of science degree and a bachelor of science degree from the College of Engineering in the span of five years. Only the thesis option is available with this program. Qualified students (3.500/4.000 GPA) who are enrolled in the Department of Mechanical Engineering at Marquette University may apply for admission to this program during their undergraduate junior year. Students must submit an application to the Graduate School, indicate their interest in the five year program, and meet all other admission criteria as stated in the Application Requirements section.

Students select graduate-level courses in their senior undergraduate year as their electives; these elective courses double-count toward the undergraduate and graduate degrees. However, only a maximum of 6 credit hours can apply toward the graduate degree. Upon completion of the first term as a master’s candidate, the student must petition the Graduate School to transfer courses taken as an undergraduate to the master’s degree.

Students begin their research for the thesis the summer between their junior and senior years. Their research is continued the summer between their senior and fifth years and throughout their fifth year, culminating in the preparation of a written thesis and defense.

**Mechanical Engineering Master of Engineering (M.E.) Requirements**

**Specializations:** Energy Systems, Manufacturing and Materials Systems, Mechanical Systems

Upon enrolling in the master of engineering program in mechanical engineering, a student selects one of three areas of specialization: energy systems, manufacturing and materials systems, or mechanical systems. A curriculum is designed along with an academic adviser which is specific to the goals of the individual student. The program includes course work in engineering, mathematics and science with the following requirements:

- 30 credit hours of course work selected from the requirements below for each specialization.
- A minimum of 3 credit hours of an approved math course (MEEN 6101 Advanced Engineering Analysis 1, MEEN 6102 Advanced Engineering Analysis 2 or MEEN 6103 Approximate Methods in Engineering Analysis), or equivalent. An equivalent math requirement from another department must be approved by the student’s adviser and the director of graduate studies.
- A minimum of one half of the total course work must be at the 6000 level.
• A minimum of one half of the total course work must be taken from the Department of Mechanical Engineering. No more than 12 credit hours may be taken outside the Department of Mechanical Engineering and these courses must be approved by the student’s adviser and the director of graduate studies.

• At most, a maximum of 3 credit hours of an Independent Study course may be included in the course work total.

• Completion of a capstone comprehensive examination consisting of two parts:
  1. A mathematics portion drawn from material presented in MEEN 6101 Advanced Engineering Analysis 1.
  2. An area of specialization portion drawn from material presented in required specialization courses within the area of the selected specialization.

• A maximum of 6 credit hours of graduate-level credit from other approved institutions may be accepted toward the requirement of the degree as long as requirements are met, and prior approval must be received from the student’s adviser and director of graduate studies.

## Specialization Requirements

### Energy Systems

**Required math course:**

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<thead>
<tr>
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<tbody>
<tr>
<td>MEEN 6101</td>
<td>Advanced Engineering Analysis 1</td>
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<tr>
<td>or MEEN 6102</td>
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<td>or MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
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</tbody>
</table>

**Required specialization courses:**

<table>
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<tr>
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<tbody>
<tr>
<td>MEEN 5350</td>
<td>Transport Phenomena</td>
</tr>
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<td>MEEN 5360</td>
<td>Intermediate Thermodynamics</td>
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</table>

**Additional course work chosen from the following:**

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<tr>
<td>MEEN 5260</td>
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<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Method</td>
</tr>
<tr>
<td>MEEN 5310</td>
<td>Combustion: Thermochemistry, Kinetics and Applications</td>
</tr>
<tr>
<td>MEEN 5325</td>
<td>Intermediate Fluid Mechanics</td>
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<td>Experimental Design</td>
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<td>Approximate Methods in Engineering Analysis</td>
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<tr>
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<td>Multiscale Material Modeling</td>
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<td>Turbulence</td>
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<td>Statistical Thermodynamics</td>
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<td>Thermal Radiation Heat Transfer</td>
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<td>Convective Heat and Mass Transfer</td>
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<tr>
<td>MEEN 6360</td>
<td>Computational Fluid Mechanics</td>
</tr>
<tr>
<td>MEEN 6370</td>
<td>Combustion Chemistry and Mechanisms</td>
</tr>
<tr>
<td>MEEN 6931</td>
<td>Topics in Mechanical Engineering</td>
</tr>
<tr>
<td>MEEN 6960</td>
<td>Seminar in Mechanical Engineering</td>
</tr>
<tr>
<td>MEEN 6995</td>
<td>Independent Study in Mechanical Engineering</td>
</tr>
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</table>

**Additional courses as approved by adviser (no more than 6 credit hours total)**

**Total Credit Hours**

<table>
<thead>
<tr>
<th>Course</th>
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</table>

### Manufacturing and Materials Systems

**Required math course:**

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<tr>
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</tr>
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<tbody>
<tr>
<td>MEEN 6101</td>
<td>Advanced Engineering Analysis 1</td>
</tr>
<tr>
<td>or MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
</tr>
<tr>
<td>or MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
</tbody>
</table>

**Required specialization courses:**

<table>
<thead>
<tr>
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<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 5410</td>
<td>Experimental Design</td>
</tr>
<tr>
<td>MEEN 5440</td>
<td>Processing and Forming of Materials</td>
</tr>
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</table>

**Additional course work chosen from the following:**

<table>
<thead>
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<tr>
<td></td>
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</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
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</tr>
<tr>
<td>MEEN 5220</td>
<td>Intermediate Dynamics</td>
</tr>
<tr>
<td>MEEN 5240</td>
<td>Polymers and Polymer Composites</td>
</tr>
<tr>
<td>MEEN 5245</td>
<td>Fatigue and Fracture Mechanics</td>
</tr>
<tr>
<td>MEEN 5260</td>
<td>Introduction to Continuum Mechanics</td>
</tr>
<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Method</td>
</tr>
<tr>
<td>MEEN 5275</td>
<td>Mechatronics</td>
</tr>
<tr>
<td>MEEN 5420</td>
<td>Failure Analysis</td>
</tr>
<tr>
<td>MEEN 5430</td>
<td>Powder Metallurgy</td>
</tr>
<tr>
<td>MEEN 5450</td>
<td>Mechanical Behavior of Materials</td>
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<tr>
<td>MEEN 5460</td>
<td>Work Measurement and Facilities Design</td>
</tr>
<tr>
<td>MEEN 5475</td>
<td>Ergonomics</td>
</tr>
<tr>
<td>MEEN 5485</td>
<td>Welding Engineering</td>
</tr>
<tr>
<td>MEEN 5931</td>
<td>Topics in Mechanical Engineering</td>
</tr>
<tr>
<td>MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
</tr>
<tr>
<td>MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
<tr>
<td>MEEN 6250</td>
<td>Industrial Robotics</td>
</tr>
<tr>
<td>MEEN 6260</td>
<td>Multiscale Material Modeling</td>
</tr>
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<td>MEEN 6470</td>
<td>Statistical Methods in Engineering</td>
</tr>
<tr>
<td>MEEN 6473</td>
<td>Computer Integrated Manufacturing</td>
</tr>
<tr>
<td>MEEN 6475</td>
<td>Advanced Ergonomics/Human Factors Engineering</td>
</tr>
<tr>
<td>MEEN 6480</td>
<td>Metal Forming</td>
</tr>
<tr>
<td>MEEN 6931</td>
<td>Topics in Mechanical Engineering</td>
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<tr>
<td>MEEN 6960</td>
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<td>Independent Study in Mechanical Engineering</td>
</tr>
</tbody>
</table>

Additional courses as approved by adviser (no more than 6 credit hours total)

### Mechanical Systems

#### Required math course:

- 3

- **MEEN 6101** or **MEEN 6102** or **MEEN 6103**
  - Advanced Engineering Analysis 1
  - Advanced Engineering Analysis 2
  - Approximate Methods in Engineering Analysis

#### Required specialization courses:

- 6

- MEEN 5220
  - Intermediate Dynamics

- MEEN 5230
  - Intermediate Mechanics of Materials

#### Additional course work chosen from the following:

- 21

- MEEN 5240
  - Polymers and Polymer Composites

- MEEN 5245
  - Fatigue and Fracture Mechanics

- MEEN 5250
  - Design of Machine Elements 2

- MEEN 5260
  - Introduction to Continuum Mechanics

- MEEN 5265
  - Intermediate Finite Element Method

- MEEN 5270
  - Physical Systems Modeling

- MEEN 5275
  - Mechatronics

- MEEN 5410
  - Experimental Design

- MEEN 5420
  - Failure Analysis

- MEEN 5450
  - Mechanical Behavior of Materials

- MEEN 5570
  - Biomaterials Science and Engineering

- MEEN 5931
  - Topics in Mechanical Engineering

- MEEN 6102
  - Advanced Engineering Analysis 2

- MEEN 6103
  - Approximate Methods in Engineering Analysis

- MEEN 6220
  - Advanced Dynamics

- MEEN 6225
  - Advanced Vibrations

Total Credit Hours: 30
**Master's Learning Outcomes**

1. Apply knowledge of specialized mechanical engineering concepts in engineering analysis and design in a chosen area of specialization.
2. Effectively communicate ideas on design and analysis to peers, clients and customers.

**Mechanical Engineering Doctoral Requirements**

**Specializations:** Energy Systems, Manufacturing and Materials Systems, Mechanical Systems

A doctoral student must complete a program of study prepared in collaboration with their permanent adviser. This program of study is outlined on an approved Doctoral Program Planning Form which must be submitted within the first year of the student’s doctoral studies. The program requires the following:

- 48 credit hours of course work beyond the baccalaureate degree.
- 12 credit hours of dissertation work.
- At least 6 credit hours of an approved MEEN math course or equivalent. An equivalent math requirement from another department must be approved by the student’s adviser and the director of graduate studies.
- Continuous participation in the department graduate seminar series (MEEN 6960 Seminar in Mechanical Engineering).
- Doctoral students are required to submit a refereed journal publication and a conference proceeding prior to graduation. The requirement is submission, not necessarily publication.
- At least one half of the total course work must be at the 6000 level.
- At least one-half of the total course work must be taken from the Department of Mechanical Engineering. No more than 12 credit hours may be taken outside the Department of Mechanical Engineering and these courses must be approved by the student's adviser and the director of graduate studies.
- Completion of all university Graduate School requirements.
- Full-time enrollment.
- A maximum of 3 credit hours of an Independent Study course may be included in the course work total.
- A maximum of 6 credit hours of graduate-level credit from other accredited institutions may be accepted toward the requirement of the degree as long as requirements are met, and prior approval must be received from the student's adviser and director of graduate studies.

In cases in which the student enters the program with a master’s degree in mechanical engineering or a closely related field, the student may request (in writing) that the department and the Graduate School allow credits from the master’s degree to satisfy up to 24 credit hours of the required course work.

A doctoral student must complete a departmental written proficiency exam prior to completion of the Marquette University doctoral residency requirement. This exam is comprised of two components. One component assesses proficiency in engineering mathematics and the other assesses proficiency in the student’s declared area of specialization: energy systems, manufacturing and materials systems, or mechanical systems. This examination is based upon material presented in the advanced undergraduate and master’s degree level course work (approved math courses are MEEN 6101 Advanced Engineering Analysis 1, MEEN 6102 Advanced Engineering Analysis 2 and MEEN 6103 Approximate Methods in Engineering Analysis).

A student must pass a doctoral qualifying examination (DQE) administered by their doctoral committee within one academic year after completing course work requirements. This exam must be passed at least one year prior to the submission and successful public defense of the dissertation. The dissertation must represent an original research contribution and demonstrate both high scholarly achievement and the ability to conduct independent research.

**Specialization Requirements**

**Energy Systems**

A specialization in energy systems typically entails advanced study of (a) thermodynamics, fluid mechanics, heat and mass transfer and combustion; (b) the application of these principles to phenomena and devices which constitute energy-conversion systems; and (c) the analysis, simulation and design of
Mechanical Engineering (MEEN)

such systems as well as plants; e.g., chemical, metallurgical, food, etc., which are energy-intensive. Current research topics include: plant optimization, cogeneration systems, fluid mechanics and heat transfer in surface mount technology, engine emissions/process effluents and jet engine propulsion systems, energy dispersive materials, combustion and soot modeling.

Required math courses:
- MEEN 6101 Advanced Engineering Analysis 1 3
- MEEN 6102 Advanced Engineering Analysis 2 3
  or MEEN 6103 Approximate Methods in Engineering Analysis

Required specialization courses:
- MEEN 5350 Transport Phenomena 3
- MEEN 5360 Intermediate Thermodynamics 3

Additional requirements:
- MEEN 6960 Seminar in Mechanical Engineering (taken every term) 0
- MEEN 8999 Doctoral Dissertation 12

Additional course work chosen from the following: 36
- MEEN 5260 Introduction to Continuum Mechanics
- MEEN 5265 Intermediate Finite Element Method
- MEEN 5310 Combustion: Thermochemistry, Kinetics and Applications
- MEEN 5325 Intermediate Fluid Mechanics
- MEEN 5410 Experimental Design
- MEEN 5931 Topics in Mechanical Engineering
- MEEN 6102 Advanced Engineering Analysis 2
- MEEN 6103 Approximate Methods in Engineering Analysis
- MEEN 6260 Multiscale Material Modeling
- MEEN 6310 Advanced Fluid Mechanics
- MEEN 6320 Turbulence
- MEEN 6330 Statistical Thermodynamics
- MEEN 6340 Thermal Radiation Heat Transfer
- MEEN 6350 Convective Heat and Mass Transfer
- MEEN 6360 Computational Fluid Mechanics
- MEEN 6370 Combustion Chemistry and Mechanisms
- MEEN 6931 Topics in Mechanical Engineering
- MEEN 6995 Independent Study in Mechanical Engineering

Total Credit Hours 60

Manufacturing and Materials Systems

A specialization in manufacturing and materials systems typically entails advanced study in (a) evaluation of materials and their behavior; (b) processes for changing material shape and properties; (c) approaches to economizing complex systems; (d) material-man-machine interfaces; and (e) analysis of the manufacturing process. Normally, each of these multi-disciplinary areas requires certain core courses along with specialized studies, which may include advanced courses in other engineering disciplines, courses in mathematics and statistics and/or courses in business administration. Current research topics include: cellular manufacturing, polishing and mass finishing processes, flexible assembly, robotic systems, production integration, ergonomics, reliability/quality estimation, human performance and safety evaluation, and materials forming and joining processes.

Required math courses:
- MEEN 6101 Advanced Engineering Analysis 1 3
- MEEN 6102 Advanced Engineering Analysis 2 3
  or MEEN 6103 Approximate Methods in Engineering Analysis

Required specialization courses:
- MEEN 5410 Experimental Design 3
- MEEN 5440 Processing and Forming of Materials 3

Additional requirements:
- MEEN 6960 Seminar in Mechanical Engineering (taken every term) 0
- MEEN 8999 Doctoral Dissertation 12

Additional course work chosen from the following: 36
### Mechanical Systems

A specialization in mechanical systems typically entails advanced study of (a) mechanical system design and analysis; and (b) modeling, simulation, and control. Mechanical design and analysis focuses on the use of physical and mathematical principles to understand the behavior of mechanical systems. It includes computer-aided optimal design, such as the design of multi-body, multi-degree-of-freedom mechanical systems. The modeling, simulation and control area involves the study of theoretical mechanics in conjunction with computational applications including advanced dynamics, kinematics and stress analysis. Other applications include the modeling and control of manufacturing processes, including robotics and automated deformation processing. Current research areas include: composite and polymeric materials, control in automated assembly, design of compliant mechanisms, metal cutting/forming mechanics, finite element methods and multiscale material modeling.

#### Required math courses:

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<tr>
<th>Course</th>
<th>Title</th>
<th>Credit Hours</th>
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<td>MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
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<tr>
<td>or MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
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#### Required specialization courses:

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<td>MEEN 5230</td>
<td>Intermediate Mechanics of Materials</td>
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#### Additional requirements:

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<td>MEEN 8999</td>
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#### Additional course work chosen from the following:

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<td>MEEN 5250</td>
<td>Design of Machine Elements 2</td>
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<td>Introduction to Continuum Mechanics</td>
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<td>MEEN 5265</td>
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<td>MEEN 5275</td>
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<td>Experimental Design</td>
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<td>MEEN 5450</td>
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<td>MEEN 6995</td>
<td>Independent Study in Mechanical Engineering</td>
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</tr>
</tbody>
</table>

Total Credit Hours 60

**Doctoral Learning Outcomes**

1. Apply knowledge of advanced concepts (i.e., concepts beyond those learned during the master of science program) in engineering mathematics and two out of three areas of specializations offered in the department (mechanical systems, energy systems, manufacturing and materials systems).
2. Communicate ideas (specific to an area of specialization) via peer reviewed published and/or presented materials.
3. Conduct original research in a chosen area of specialization.