Mechanical Engineering (MEEN)

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

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.¹
3. Three letters of recommendation.
4. A brief statement of purpose (not required for master of engineering/M.E. applicants) and copies of any published work, including previous master’s theses 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.

¹ 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, EECE 6010 Advanced Engineering Mathematics), 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 dissipative materials, and soot modeling.

Required math course:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credit</th>
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<tbody>
<tr>
<td>MEEN 6101</td>
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<tr>
<td>or MEEN 6102</td>
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<tr>
<td>or MEEN 6103</td>
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<tr>
<td>or EECE 6010</td>
<td>Advanced Engineering Mathematics</td>
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Required specialization courses:

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<tr>
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<tbody>
<tr>
<td>MEEN 5325</td>
<td>Intermediate Fluid Mechanics</td>
</tr>
<tr>
<td>MEEN 5360</td>
<td>Intermediate Thermodynamics</td>
</tr>
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Additional requirements:

<table>
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<th>Course Code</th>
<th>Course Name</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:

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<tr>
<th>Course Code</th>
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<tbody>
<tr>
<td>MEEN 5260</td>
<td>Introduction to Continuum Mechanics</td>
</tr>
<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Methods</td>
</tr>
<tr>
<td>MEEN 5310</td>
<td>Combustion: Thermochemistry, Kinetics and Applications</td>
</tr>
<tr>
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<td>MEEN 6995</td>
<td>Independent Study in Mechanical Engineering</td>
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</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.
### Mechanical Engineering (MEEN)

#### Required Math Course:
- **MEEN 6101**: Advanced Engineering Analysis 1
- or **MEEN 6102**: Advanced Engineering Analysis 2
- or **MEEN 6103**: Approximate Methods in Engineering Analysis
- or **EECE 6010**: Advanced Engineering Mathematics

#### Required Specialization Courses:
- **MEEN 5410**: Experimental Design
- **MEEN 5440**: Processing and Forming of Materials

#### Additional Requirements:
- **MEEN 6960**: Seminar in Mechanical Engineering (taken every term) - 0 credits
- **MEEN 6999**: Master's Thesis - 6 credits

#### Additional Course Work Chosen from the Following:
- **MEEN 5220**: Intermediate Dynamics
- **MEEN 5240**: Polymers and Polymer Composites
- **MEEN 5245**: Fatigue and Fracture Mechanics
- **MEEN 5260**: Introduction to Continuum Mechanics
- **MEEN 5265**: Intermediate Finite Element Methods
- **MEEN 5275**: Mechatronics
- **MEEN 5420**: Failure Analysis
- **MEEN 5430**: Powder Metallurgy
- **MEEN 5450**: Mechanical Behavior of Materials
- **MEEN 5460**: Work Measurement and Facilities Design
- **MEEN 5475**: Ergonomics
- **MEEN 5485**: Welding Engineering
- **MEEN 5931**: Topics in Mechanical Engineering
- **MEEN 6102**: Advanced Engineering Analysis 2
- **MEEN 6103**: Approximate Methods in Engineering Analysis
- **MEEN 6250**: Industrial Robotics
- **MEEN 6260**: Multiscale Material Modeling
- **MEEN 6470**: Statistical Methods in Engineering
- **MEEN 6473**: Computer Integrated Manufacturing
- **MEEN 6475**: Advanced Ergonomics/Human Factors Engineering
- **MEEN 6480**: Metal Forming
- **MEEN 6931**: Topics in Mechanical Engineering
- **MEEN 6995**: Independent Study in Mechanical Engineering

**Total Credit Hours: 30**

### 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:
- **MEEN 6101**: Advanced Engineering Analysis 1
- or **MEEN 6102**: Advanced Engineering Analysis 2
- or **MEEN 6103**: Approximate Methods in Engineering Analysis
- or **EECE 6010**: Advanced Engineering Mathematics

#### Required Specialization Courses:
- **MEEN 5220**: Intermediate Dynamics
- **MEEN 5230**: Intermediate Mechanics of Materials
Additional requirements:

<table>
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<tr>
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<th>Credit Hours</th>
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<td>MEEN 6960</td>
<td>Seminar in Mechanical Engineering (taken every term)</td>
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<td>MEEN 6999</td>
<td>Master's Thesis</td>
<td>6</td>
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<td>Polymers and Polymer Composites</td>
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<td>MEEN 5245</td>
<td>Fatigue and Fracture Mechanics</td>
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<td>MEEN 5250</td>
<td>Design of Machine Elements 2</td>
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<td>MEEN 5260</td>
<td>Introduction to Continuum Mechanics</td>
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<td>Intermediate Finite Element Methods</td>
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<td>MEEN 5275</td>
<td>Mechatronics</td>
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<td>MEEN 5410</td>
<td>Experimental Design</td>
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<td>MEEN 5420</td>
<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>MEEN 6220</td>
<td>Advanced Dynamics</td>
</tr>
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<td>MEEN 6225</td>
<td>Advanced Vibrations</td>
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<tr>
<td>MEEN 6230</td>
<td>Advanced Mechanics of Materials</td>
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<td>MEEN 6240</td>
<td>Composite Materials</td>
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<td>Industrial Robotics</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 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 count toward both 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, MEEN 6103 Approximate Methods in Engineering Analysis or EECE 6010 Advanced Engineering Mathematics), 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>
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<tbody>
<tr>
<td>MEEN 6101</td>
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**Required specialization courses:**

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<td>Intermediate Thermodynamics</td>
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<td>Introduction to Continuum Mechanics</td>
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<td>MEEN 5265</td>
<td>Intermediate Finite Element Methods</td>
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<td>MEEN 5310</td>
<td>Combustion: Thermochemistry, Kinetics and Applications</td>
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<tr>
<td>MEEN 5350</td>
<td>Transport Phenomena</td>
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<td>Experimental Design</td>
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<td>Topics in Mechanical Engineering</td>
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<td>MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
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<td>Combustion Chemistry and Mechanisms</td>
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<td>Topics in Mechanical Engineering</td>
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<td>MEEN 6960</td>
<td>Seminar in Mechanical Engineering</td>
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<td>MEEN 6995</td>
<td>Independent Study in Mechanical Engineering</td>
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**Additional courses as approved by adviser (no more than 6 credit hours total)**

**Total Credit Hours:**

30

#### Manufacturing and Materials Systems

**Required math course:**

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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>
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**Total Credit Hours:**

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<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td>MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
</tr>
<tr>
<td>or ECEE 6010</td>
<td>Advanced Engineering Mathematics</td>
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</table>

**Required specialization courses:** 6

- MEEN 5410 Experimental Design
- MEEN 5440 Processing and Forming of Materials

**Additional course work chosen from the following:** 21

- MEEN 5220 Intermediate Dynamics
- MEEN 5240 Polymers and Polymer Composites
- MEEN 5245 Fatigue and Fracture Mechanics
- MEEN 5260 Introduction to Continuum Mechanics
- MEEN 5265 Intermediate Finite Element Methods
- MEEN 5275 Mechatronics
- MEEN 5420 Failure Analysis
- MEEN 5430 Powder Metallurgy
- MEEN 5450 Mechanical Behavior of Materials
- MEEN 5460 Work Measurement and Facilities Design
- MEEN 5475 Ergonomics
- MEEN 5485 Welding Engineering
- MEEN 5931 Topics in Mechanical Engineering
- MEEN 6102 Advanced Engineering Analysis 2
- MEEN 6103 Approximate Methods in Engineering Analysis
- MEEN 6250 Industrial Robotics
- MEEN 6260 Multiscale Material Modeling
- MEEN 6470 Statistical Methods in Engineering
- MEEN 6473 Computer Integrated Manufacturing
- MEEN 6475 Advanced Ergonomics/Human Factors Engineering
- MEEN 6480 Metal Forming
- MEEN 6931 Topics in Mechanical Engineering
- MEEN 6960 Seminar in Mechanical Engineering
- MEEN 6995 Independent Study in Mechanical Engineering

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

**Total Credit Hours**

30

### Mechanical Systems

**Required math course:** 3

- MEEN 6101 Advanced Engineering Analysis 1
- or MEEN 6102 Advanced Engineering Analysis 2
- or MEEN 6103 Approximate Methods in Engineering Analysis
- or ECEE 6010 Advanced Engineering Mathematics

**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 Methods
- MEEN 5270 Physical Systems Modeling
- MEEN 5275 Mechatronics
- MEEN 5410 Experimental Design
- MEEN 5420 Failure Analysis
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, MEEN 6103 Approximate Methods in Engineering Analysis and EECE 6010 Advanced Engineering Mathematics).

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 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.

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<td>MEEN 5325</td>
<td>Intermediate Fluid Mechanics</td>
</tr>
<tr>
<td>MEEN 5360</td>
<td>Intermediate Thermodynamics</td>
</tr>
</tbody>
</table>

**Additional requirements:**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 6960</td>
<td>Seminar in Mechanical Engineering (taken every term)</td>
</tr>
<tr>
<td>MEEN 8999</td>
<td>Doctoral Dissertation</td>
</tr>
</tbody>
</table>

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

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<tr>
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</tr>
<tr>
<td>MEEN 5265</td>
<td>Intermediate Finite Element Methods</td>
</tr>
<tr>
<td>MEEN 5310</td>
<td>Combustion: Thermochemistry, Kinetics and Applications</td>
</tr>
<tr>
<td>MEEN 5350</td>
<td>Transport Phenomena</td>
</tr>
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<td>MEEN 5410</td>
<td>Experimental Design</td>
</tr>
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<td>MEEN 5931</td>
<td>Topics in Mechanical Engineering</td>
</tr>
<tr>
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<td>Advanced Engineering Analysis 2</td>
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<tr>
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<tr>
<td>MEEN 6260</td>
<td>Multiscale Material Modeling</td>
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<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>
<tr>
<td>MEEN 6350</td>
<td>Convective Heat and Mass Transfer</td>
</tr>
<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 6995</td>
<td>Independent Study in Mechanical Engineering</td>
</tr>
</tbody>
</table>

**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:**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>MEEN 6101</td>
<td>Advanced Engineering Analysis 1</td>
</tr>
<tr>
<td>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>

**Total Credit Hours** 60
Mechanical Engineering (MEEN)

Required specialization courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEEN 5410</td>
<td>Experimental Design</td>
<td>3</td>
</tr>
<tr>
<td>MEEN 5440</td>
<td>Processing and Forming of Materials</td>
<td>3</td>
</tr>
</tbody>
</table>

Additional requirements:

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<tr>
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</tr>
<tr>
<td>MEEN 8999</td>
<td>Doctoral Dissertation</td>
<td>12</td>
</tr>
</tbody>
</table>

Additional course work chosen from the following: 36

- MEEN 5220 Intermediate Dynamics
- MEEN 5240 Polymers and Polymer Composites
- MEEN 5245 Fatigue and Fracture Mechanics
- MEEN 5260 Introduction to Continuum Mechanics
- MEEN 5265 Intermediate Finite Element Methods
- MEEN 5275 Mechatronics
- MEEN 5420 Failure Analysis
- MEEN 5430 Powder Metallurgy
- MEEN 5450 Mechanical Behavior of Materials
- MEEN 5460 Work Measurement and Facilities Design
- MEEN 5475 Ergonomics
- MEEN 5485 Welding Engineering
- MEEN 5931 Topics in Mechanical Engineering
- MEEN 6102 Advanced Engineering Analysis 2
- MEEN 6103 Approximate Methods in Engineering Analysis
- MEEN 6250 Industrial Robotics
- MEEN 6260 Multiscale Material Modeling
- MEEN 6470 Statistical Methods in Engineering
- MEEN 6473 Computer Integrated Manufacturing
- MEEN 6475 Advanced Ergonomics/Human Factors Engineering
- MEEN 6480 Metal Forming
- MEEN 6931 Topics in Mechanical Engineering
- MEEN 6995 Independent Study in Mechanical Engineering

Total Credit Hours 60

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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<tbody>
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<tr>
<td>MEEN 6102</td>
<td>Advanced Engineering Analysis 2</td>
<td>3</td>
</tr>
<tr>
<td>or MEEN 6103</td>
<td>Approximate Methods in Engineering Analysis</td>
<td></td>
</tr>
<tr>
<td>or EECE 6010</td>
<td>Advanced Engineering Mathematics</td>
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- MEEN 5260 Introduction to Continuum Mechanics
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- MEEN 6480 Metal Forming
- MEEN 6931 Topics in Mechanical Engineering
- MEEN 6995 Independent Study in Mechanical Engineering

Total Credit Hours 60
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 Methods
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
MEEN 6230  Advanced Mechanics of Materials
MEEN 6240  Composite Materials
MEEN 6250  Industrial Robotics
MEEN 6260  Multiscale Material Modeling
MEEN 6931  Topics in Mechanical Engineering
MEEN 6995  Independent Study in Mechanical Engineering

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.

Courses

MEEN 5220. Intermediate Dynamics. 3 cr. hrs.
Develop an understanding of the principles of 3D rigid body kinematics (motion) and kinetics (forces and accelerations). Use these principles to analyze the dynamic behavior of mechanical systems. Learn to use analytical mechanics tools including virtual work and Lagrange's method. Develop a systematic approach for solving engineering problems.

Review of beam theory; asymmetric bending, shear center, thin-walled sections; torsion of non-circular sections, open and closed thin-walled sections; energy methods, Castigliano's second theorem, statically indeterminate structures, internal static indeterminacy; curved beams.

MEEN 5240. Polymers and Polymer Composites. 3 cr. hrs.
Introduction to physical/chemical structure of polymers, polymer characterization, polymer material properties and mechanical testing methods, elastic and viscoelastic polymer response, processing methods, composite materials and the selection of polymers in design applications.

MEEN 5245. Fatigue and Fracture Mechanics. 3 cr. hrs.
Application of fatigue and fracture models to engineering design. Stress-life (high-cycle), strain-life (low-cycle), and fatigue crack growth models for fatigue. Introduction to linear elastic fracture mechanics. Statistical considerations in failure. Fail-safe design practices. Includes illustrative case studies.

MEEN 5250. Design of Machine Elements 2. 3 cr. hrs.
Detailed design of gears and cams. Emphasizes integration of dynamics into design of machinery. Topics include balancing of machinery, selection of motors and critical frequency analysis, and miscellaneous power transmission components. Use of spreadsheets and computer programs to assist in the design of various components.

MEEN 5260. Introduction to Continuum Mechanics. 3 cr. hrs.
Introduction to tensor notation; tensor analysis and coordinate system invariance; analysis of stress, strain and rate of strain for infinitesimal and finite deformation; application of Newtonian mechanics to deformable media; mechanical constitutive equations; field equations for solid and fluid mechanics.
MEEN 5250. Intermediate Finite Element Method. 3 cr. hrs.
Introduces the finite element solution method for linear, static problems. Includes calculation of element stiffness matrices, assembly of global stiffness matrices, exposure to various finite element solution methods, and numerical integration. Emphasizes structural mechanics, and also discusses heat transfer and fluid mechanics applications in finite element analysis. Computer assignments include development of finite element code (FORTRAN or C) and also use of commercial finite element software (ANSYS and/or MARC). Prereq: MEEN 3260 or equiv.

MEEN 5270. Physical Systems Modeling. 3 cr. hrs.

MEEN 5275. Mechatronics. 3 cr. hrs.
Mechatronics, as an engineering discipline, is the synergistic combination of mechanical engineering, electronics, control engineering, and computer science, all integrated through the design process. This course covers mechatronic system design, modeling and analysis of dynamic systems, control sensors and actuators, analog and digital control electronics, interfacing sensors and actuators to a microcomputer/microcontroller, discrete and continuous controller design, and real-time programming for control.

MEEN 5310. Combustion: Thermochemistry, Kinetics and Applications. 3 cr. hrs.
Fundamentals of combustion and chemical kinetics, with applications to engines and combustion devices. Study of fluid flow, thermodynamics, combustion, heat transfer and friction phenomena, and fuel properties relevant to engine power, efficiency and emissions. Examination of spark-ignition, diesel, stratified charge, HCCI, mixed-cycle and gas turbine engines.

MEEN 5325. Intermediate Fluid Mechanics. 3 cr. hrs.
Intermediate Fluid Mechanics continues to develop fluid mechanic concepts, building on a working knowledge of the Reynolds Transport Theorem. Topics include: differential analysis, irrational flow theory, boundary layer theory and compressible flow theory. Both laminar and turbulent flows are discussed. Some working knowledge of computer programming is necessary.

MEEN 5330. Optics, Lasers and Spectroscopy in Engineering. 3 cr. hrs.
Topical overview on the uses of optics, lasers, and spectroscopic measurement techniques in engineering and scientific disciplines. Technical content includes basic principles of geometric optics, principles behind and characteristics of laser operation, and linear spectroscopy. Emphasis on absorption and emission techniques for sensor development.

MEEN 5350. Transport Phenomena. 3 cr. hrs.
Includes three closely related topics: fluid dynamics, mass transfer, and heat transfer. Fluid dynamics involves the transport of momentum, mass transfer is concerned with the transport of mass of various chemical species, and heat transfer deals with the transport of energy. In practice, rarely are these phenomena acting alone. Develops a more cohesive understanding of these interrelated processes.

MEEN 5360. Intermediate Thermodynamics. 3 cr. hrs.
Covers fundamentals of thermodynamics, including classical and statistical approaches with application to equilibrium and non-equilibrium, non-reactive and reactive systems. May cover topics relevant to micro/nanoscale and biological systems.

MEEN 5410. Experimental Design. 3 cr. hrs.
Application of statistical concepts to design engineering experiments to improve quality, production techniques, and reliability. Use and advantages of various models; factorial, fractional factorial, orthogonal arrays and fractional designs.

MEEN 5420. Failure Analysis. 3 cr. hrs.
Methodology of failure analysis. Studies of brittle fracture, ductile fracture, fatigue, stress corrosion and electro-chemical corrosion as applied to the failure of metals. Involves some laboratory work and analyses of a variety of metallurgical failures.

MEEN 5430. Powder Metallurgy. 3 cr. hrs.
Introduces a modern technology with growing importance. Covers the basics of powder metallurgy with main emphasis on sintered steel. The primary topics covered are powder production, die compacting, sintering theory and practice, full density processing, properties under static and dynamic loading conditions.

MEEN 5440. Processing and Forming of Materials. 3 cr. hrs.
Solidification and microstructural development in metal casting with an overview of selected melting processes. Overview of primary and secondary working principles involved in ferrous materials processing. Stress based and finite element analyses are applied to both sheet and bulk forming to develop a fundamental understanding of deformation processing principles and technology associated with processes such as drawing, open and closed die forging and rolling.

MEEN 5450. Mechanical Behavior of Materials. 3 cr. hrs.

MEEN 5460. Work Measurement and Facilities Design. 3 cr. hrs.
Concentrates on how to quantify work and how to design work tasks, based on measurement and methods engineering, to achieve optimal performance. Involves analysis and evaluation of facilities for industrial and service operations and designing facilities, regardless of size, for various types of operations.
Overview of computer integrated production systems, which include computer numerical control, industrial robotics, material transport and storage systems, automated production lines, flexible manufacturing systems, quality control systems, CAD/CAM, production planning and control, just-in-time and lean manufacturing.

MEEN 5475. Ergonomics. 3 cr. hrs.
Ergonomics maximizes the health and safety of workers, while maintaining productivity and quality. Covers biomechanical and physiologic aspects of workplace design, such as engineering anthropometry, cumulative trauma disorders, (including carpal tunnel syndrome), low back injuries, hand tool design and evaluation, methods of surveillance in industrial environments, modeling, and ergonomics guidelines. Laboratory experiences are offered to demonstrate ergonomic principles and also provide students with hands-on experience in collecting data and conducting experiments.

MEEN 5485. Welding Engineering. 3 cr. hrs.
Arc welding physics, fundamentals of power supplies and welding circuits, fusion and solid-state welding processes, weld testing, analysis of welded joints, demonstrations using various processes.

MEEN 5570. Biomaterials Science and Engineering. 3 cr. hrs.
Designed to introduce the uses of materials in the human body for the purposes of healing, correcting deformities and restoring lost function. The science aspect of the course encompasses topics including: characterization of material properties, biocompatibility and past and current uses of materials for novel devices that are both biocompatible and functional for the life of the implanted device. Projects allow students to focus and gain knowledge in an area of biomaterials engineering in which they are interested. Same as BIEN 4420.

MEEN 5931. Topics in Mechanical Engineering. 3 cr. hrs.
Topics may include energy conversion, mechanical analysis and design, and manufacturing systems.

MEEN 6101. Advanced Engineering Analysis 1. 3 cr. hrs.

MEEN 6102. Advanced Engineering Analysis 2. 3 cr. hrs.

MEEN 6103. Approximate Methods in Engineering Analysis. 3 cr. hrs.
Treatment of approximate methods for solving various problems in engineering. Matrix methods, variational methods (e.g., Ritz, Galerkin, etc.), finite difference methods, finite element method.

MEEN 6220. Advanced Dynamics. 3 cr. hrs.
Kinematics of particles and rigid bodies. Basic principles of vector mechanics. Variational principles. Basic principles of analytical mechanics. Prereq: MEEN 4220/5220 or equiv.

MEEN 6225. Advanced Vibrations. 3 cr. hrs.
Theory of vibration with applications. Natural modes of vibration for lumped parameter systems. Response of lumped systems with damping. Response of distributed parameter system including bars, beams, etc.

MEEN 6230. Advanced Mechanics of Materials. 3 cr. hrs.
Thick wall cylinders, rotating disks, initial stresses; stress concentration factors, cracks, discontinuity stresses; autofrettage, residual stresses; beams on elastic foundation, introduction to plates and shells, pressure vessel analysis. Prereq: MEEN 5230; or MEEN 5250.

MEEN 6240. Composite Materials. 3 cr. hrs.
Introduction to fiber/matrix materials systems with emphasis on continuous fiber-reinforced composites. Principles of anisotropic elasticity, classical laminate theory, and viscoelasticity. Analysis of mechanical, thermal, hygroscopic and combination loading of laminated composites. Review of manufacture/fabrication methods for advanced composites, consolidation techniques, and basic issues in the design of advanced composites. Prereq: MEEN 5240; or cons. of instr.

MEEN 6250. Industrial Robotics. 3 cr. hrs.
Fundamentals of industrial robotic systems. Covers serial and parallel manipulators, forward and inverse kinematics, differential kinematics, multi-rigid-body dynamics, trajectory planning, linear control theory, actuators and sensors, mechanism design and vision systems.

MEEN 6260. Multiscale Material Modeling. 3 cr. hrs.
Numerical and analytical techniques for modeling the micromechanics and micro-structural evolution of complex heterogeneous materials (including granular, composite, and atomic/molecular materials); techniques for transferring information between local (micro-scale) and global (macro-scale) representations of multi-scale materials. Prereq: MEEN 3260 or equiv., and MEEN 4260 or MEEN 5260 or equiv.

MEEN 6310. Advanced Fluid Mechanics. 3 cr. hrs.
Further development of fluid flow theory starting with classic potential flow solutions. Numerical and analytical techniques for both inviscid and viscous fluid flows, including boundary layer theory and stability. Transition routes and chaos with an introduction to turbulence. Prereq: MEEN 5325 or MEEN 5350 or equiv.; computer programming experience recommended.
MEEN 6320. Turbulence. 3 cr. hrs.
Advanced physical and mathematical description of fluid flow systems, including the fundamentals of turbulence motion. The development of the Reynolds stress equations, processes that govern dissipation and statistical description of scales. Includes the modeling techniques associated with turbulent velocity profiles as well as the development of zero, one and two equation closure models. Prereq: MEEN 5350 or equiv.; computer programming experience recommended.

MEEN 6330. Statistical Thermodynamics. 3 cr. hrs.

MEEN 6340. Thermal Radiation Heat Transfer. 3 cr. hrs.

MEEN 6345. Multicomponent Mass Transfer. 3 cr. hrs.
Fundamentals of Multicomponent Mass Transfer, including Maxwell-Stefan diffusion, Generalized Fick's Law, ideal and non-ideal mixtures, interphase mass transfer and film theory and multicomponent mass transfer in porous media.

MEEN 6350. Convective Heat and Mass Transfer. 3 cr. hrs.
Principles and mechanisms of convective transports of energy and of chemical species associated with laminar and turbulent flows, including condensation and boiling. Calculation of heat and mass transport coefficients. Mathematical modeling, with applications to engineering devices involving several of these processes, with and without phenomenological coupling. Prereq: MEEN 6310.

MEEN 6360. Computational Fluid Mechanics. 3 cr. hrs.
Review of the fundamental thermofluids science, mathematical and computational principles underlying modern CFD software. Utilization of software for representative applications. Individual student project devoted to a new application. Prereq: MEEN 6101 and MEEN 6320; or cons. of instr.

MEEN 6370. Combustion Chemistry and Mechanisms. 3 cr. hrs.
Advanced theoretical, experimental and numerical techniques for studying the chemistry and kinetic mechanisms of combustion. The technical content for includes theories of gas phase chemical kinetics, a discussion of experimental and theoretical techniques for evaluating kinetic rate coefficients, and strategies for the development and reduction of kinetic mechanisms intended for modeling combustion reactions. Topics relevant to statistical thermodynamics and the physical dynamics of technical flames may be covered. Prereq: MEEN 4310 or MEEN 5310 or equiv.

MEEN 6375. Turbulent Combustion. 3 cr. hrs.

MEEN 6470. Statistical Methods in Engineering. 3 cr. hrs.

MEEN 6472. Computer Integrated Manufacturing. 3 cr. hrs.
Primary objectives include the validation of the underlying philosophy behind computer integrated manufacturing and the definition of characteristics of various components which constitute a C.I.M. environment. Describes the benefits of C.I.M. and how to upgrade conventional plants to a C.I.M. operation.

MEEN 6475. Advanced Ergonomics/Human Factors Engineering. 3 cr. hrs.
Fundamentals of ergonomics/human factors engineering (HFE) with emphasis on the application of basic principles to advances in engineering applications, research, and development. Topics include: engineering anthropometry, cumulative trauma disorders, low back disorders, electromyography, biomechanical modeling, and ergonomic guidelines. Requires research papers in the above areas or in a related ergonomics/HFE field. Prereq: Cons. of instr.

MEEN 6480. Metal Forming. 3 cr. hrs.
Elements of von Mises plasticity theory-stress and deformation states, constitutive equations, and flow rules; plane and axisymmetric behavior. Solution techniques - exact, slipline theory, upper and lower bounds, finite bending, deep drawing. Prereq: MEEN 5440 or equiv.; or cons. of instr.

MEEN 6931. Topics in Mechanical Engineering. 3 cr. hrs.
Topics may include thermofluid science, mechanical analysis and design, and manufacturing systems.

MEEN 6960. Seminar in Mechanical Engineering. 0 cr. hrs.
Scholarly presentations on current topics in mechanical engineering and related areas by visiting and resident investigators. Required of all full-time graduate students. SNC/UNC grade assessment.

MEEN 6995. Independent Study in Mechanical Engineering. 1-3 cr. hrs.
Prereq: Cons. of instr. and cons. of dept. ch.

MEEN 6999. Master's Thesis. 1-6 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.
MEEN 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

MEEN 9970. Graduate Standing Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9974. Graduate Fellowship: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9975. Graduate Assistant Teaching: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9976. Graduate Assistant Research: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9984. Master's Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9985. Master's Comprehensive Examination Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9986. Master's Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9987. Doctoral Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9988. Doctoral Comprehensive Examination Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9989. Doctoral Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9994. Master's Thesis Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9995. Master's Thesis Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9996. Master's Thesis Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9997. Doctoral Dissertation Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9998. Doctoral Dissertation Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

MEEN 9999. Doctoral Dissertation Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.