

# Mechanical and Materials Engineering

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Mechanical Engineering, a major division of the engineering profession, plays a major role in our technologically advanced society. The design and manufacturing of power plants, automobiles, aircrafts, robots to improved methods of transportation and production by industrial robots, are but a few important inventions that would not have been realized without the creativity associated with the mechanical engineering profession. The mechanical engineer is a vital ingredient in most industries that require automation, computers and medical technology, as well as areas as diverse as space exploration, environmental control and bioengineering. In fact, the mechanical engineer has a direct input in all facets of modern life. There is a high demand for graduates in mechanical engineering from high technology industries throughout the United States and the developing world. The Mechanical and Materials Engineering Department at FIU takes pride in providing well educated, and technologically competent graduates to serve these industries.

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The academic program provides a well-balanced curriculum in the following areas of specialization:

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- Mechanical Systems
- **Mechanics**
- Robotics and Mechatronics
- Thermo/fluid Systems
- HVAC
- Material Characterization
- Manufacturing and Automation Systems
- Materials Science and Engineering

- Multidisciplinary Design Optimization and Inverse Design
- Computational Analysis and Distributed Parallel Computing
- **Biomechanics**
- **Biomedical Engineering**
- **Laser and Plasma** Materials Processing
- Nanomaterials
- Nanotechnology
- Electronic Packaging
- Optical Measurement and Diagnostics
- Waste Management
- Renewable Energy

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Materials Science and Engineering is a dynamic field involved in the synthesis, structure, properties and performance of materials. Advanced materials are the foundation of manufactured products and many of the technological advances of this century were enabled by the development of new materials. Materials Science and Engineering is a graduate program only, with undergraduate electives offered in the Mechanical Engineering curriculum to prepare the student for graduate education in materials science and engineering. The academic program offers specialization in metallurgy, ceramics, electronic materials, **nanomaterials** and polymers and biomaterials. There is an increasing demand for graduates in materials science and engineering, with high technology industries leading the need for graduates. In fact, many of the companies needing materials scientists and engineers did not exist 20 years ago. Because everything is made of materials and new materials, such as **nanomaterials**, are rapidly being developed, materials science and engineering is a growth field in engineering.

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Opportunities also exist for conducting research in the following Centers:

**Advanced Materials Engineering Research Institute (AMERI):** This center provides open access to research instrumentation, characterization capabilities and process development laboratories to support materials science and engineering research over the range from nanomaterials to bulk properties. **AMERI also houses a nanofabrication facility for device fabrication.**

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**The Center for the Study of Materials under Extreme Conditions (CeSMEC):** This center's research is directly geared towards the study of materials, particularly nanophase materials.

~~**Cardiovascular Engineering Center (CVEC):** This center engages multidisciplinary teams of academicians, industry engineers and clinicians in basic and applied research specifically aimed at advancing technology in the design and use of biomedical devices.~~

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~~**Hemispheric Center for Environmental Technology (HCET):** HCET, **Applied Research Center (ARC):** ARC focuses on environmental technology research and applications. The primary activity of the center is in the research of solid waste and nuclear facility decontamination and dismantlement technology.~~

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**Multidisciplinary Analysis, Inverse Design, Robust Optimization and Controls (MAIDROC) Laboratory** has a 96-processor parallel computer running Linux and MPI.

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## Graduate Certificate in Mechanical Engineering

The Graduate Certificate in Mechanical Engineering is open to students and engineers who hold a B.S. degree in engineering or a closely-related field of study from an accredited program. The objective of this certificate is to provide a vehicle for the career enhancement of practicing engineers and serve the needs of recent B.S. graduates and graduate students in other programs. The program consists of two concentration areas; Design, Mechanics and Robotics area, and Thermo-Fluids area, reflecting the diverse nature of mechanical engineering.

### Admission Requirements

The applicants for the Graduate Certificate in Mechanical Engineering must have a B.S. degree in engineering or a closely-related field from an accredited program, and have a GPA of at least 3.0 in the last two years of undergraduate studies, or a GPA of at least 2.5 in conjunction with significant related work experience

### Course Requirements

A total of 18 credit hours (6 three-credit courses) must be completed with a GPA of 3.0 or better to receive the Graduate Certificate in Mechanical Engineering. Two courses (six credits) are core courses and must be taken by all students. The remaining twelve credits may be selected from one of two concentration areas.

### Core Courses (6 credits):

EGM 5346 Computational Engineering Analysis (3)

Select one of the following two courses:

EGM 5354 Finite Element Method Applications in Mechanical Engineering (3)

EGM 6422 Advanced Computational Engineering Analysis (3)

### Elective Courses (12 credits):

Select four courses either from the (1) Design, Mechanics and Robotics area, or the (2) Thermo-Fluids area:

#### (1) Design, Mechanics and Robotics Area:

EML 5385 Identification Techniques of Mechanical Systems (3)

EML 5505 Smart Machine Design and Development (3)

EML 5530 Intermediate CAD/CAE (3)

EGM 5615 Synthesis of Engineering Mechanics (3)

EML 5808 Control Technology for Robotic Systems (3)

EML 6805 Advanced Design of Robots (3)

#### (2) Thermo-Fluids Area:

EML 5103 Intermediate Thermodynamics (3)

EML 5152 Intermediate Heat Transfer (3)

EML 5606C Advanced Refrigeration & AC systems (3)

EML 5709 Intermediate Fluid Mechanics (3)

EML 5725 Computational Fluid Dynamics (3)

## Master of Science in Mechanical Engineering

### Admission Requirements

The Department of Mechanical and Materials Engineering offers both thesis and non-thesis options for the Master's Degree in Mechanical Engineering. A student seeking the

Master's degree with or without thesis is required to pass a comprehensive oral or written examination.

All work counted for the Master's degree must be completed during the six years immediately following the date of admission.

The program provides a broad education, covering more than one field, followed by in-depth studies in areas of interest.

### Admission Requirements

The following is in addition to the University's graduate admission requirements:

1. A student seeking admission into the program must have a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution, or, in the case of foreign students, from an institution recognized in its own country as preparing students for further study at the graduate level.

2. An applicant must have achieved a "B" average, GPA of 3.0 in upper level undergraduate work and a combined V+Q score of 1100 on the Graduate Record Examination with the following minimum scores on the individual components: verbal  $\geq 350$ , and quantitative  $\geq 650$ .

3. Applicants who have not satisfied the above will be evaluated for probationary or waiver admission.

4. In addition to the above criteria, International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 213 on the TOEFL, 80 on the iBT TOEFL or 6.3 overall on the IELTS is required.

5. The GPA, GRE and TOEFL scores specified above are to be considered minimum requirements for admission. Applicants from science areas other than mechanical engineering will be expected to complete remedial undergraduate courses selected to prepare them for graduate courses in their area of interest. Full admission to the graduate program requires the completion of these background courses with no grades below 'C' and a grade point average of 3.0 or better.

### Graduation Requirements

The M.S degree will be conferred when the following conditions have been met:

1. Recommendation of the advisor and faculty of the Department.

2. Certification provided by the Department Chair, College Dean, and University Graduate School that all degree requirements have been met.

3. Completion of Completed the two applied/computational mathematics courses offered by the department, two courses outside student's major area and other courses as suggested by student's major professor and committee. ~~three department core course requirements plus the two required core courses in the student's major area.~~

4. Completion of Completed undergraduate course deficiencies specified at admission, if any, with no grades below 'C' and a GPA  $\geq 3.0$ .

5. Thesis option: Successfully completed a minimum of 30 semester hours of graduate course work as specified in an approved study plan containing at least 6 hours of 6000 level courses with a GPA  $\geq 3.0$  (the minimum successful grade is a 'C'). Not more than six semester hours transferred from another accredited graduate program that

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was not part of a previously awarded degree may be **incorporated** in the study plan) plus a minimum of six hours of masters thesis research.

Non-thesis option: Successfully completed a minimum of 33 semester hours of graduate course work as specified in an approved study plan containing at least 9 hours of 6000 level courses with a GPA  $\geq 3.0$  (not more than six semester hours transferred from another accredited graduate program that was not part of a previously awarded degree may be incorporated in the study plan).

6. Thesis option: Successful public oral defense of the thesis. Submission of the approved thesis to the Graduate School.

Non-thesis option: Successful completion of a final oral comprehensive examination covering the general objectives of the study plan.

7. Students must achieve an overall GPA  $\geq 3.0$  in all graduate work completed at FIU in their approved study plan.

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8. Students must complete **one semester of the** Graduate Seminar course.

9. Students must comply with all relevant University policies and regulations.

**Thesis Option**

A student shall complete a minimum of 24 semester credit hours of course work, plus a minimum of 6 semester credit hours of EML 6971, Master's Thesis Research, and take MME Graduate Seminar **for at least one semester.**

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The course requirements include a minimum of 12 hours of 6000-level course credit including thesis hours. A maximum of 6 credit hours of courses offered by other departments may be included among the 24 course hour minimum. A maximum of three credit hours of approved independent studies, EML 6908, may be counted toward the M.S. thesis degree. A maximum of six graduate credit hours can be transferred from other accredited institutions provided that the courses have not been used for another degree and have a minimum letter grade of 'B' and meet university requirements. Transfer courses must be approved by the advisor and Graduate Coordinator.

Early in the program (before the middle of the second term) the student and advisor will complete a study plan that specifies the courses that will comprise the program.

When the thesis research is completed, the student should schedule a defense with an examining committee appointed through the Graduate School consisting of a least three faculty members (at least two of whom should be from the MME Department). The thesis, with an approval cover letter from the advisor, should be given to the examining committee for review not less than four weeks before the scheduled defense. The candidate should prepare to summarize the thesis in the manner of a technical paper using appropriate visual aids in 40 minutes or less. Following the presentation, the candidate will answer questions related to the work from the audience and/or the committee. At the conclusion of the defense, the committee will agree on the outcome -pass or fail- and report the results to the Graduate School. Following the exam the student will implement the committee's suggestions for improving the draft document. Each committee member must sign the approval form bound in the final document. Copies of the approved thesis must be provided to the advisor, department, and the library.

**Non-Thesis Option**

A student shall complete a minimum of 33 semester credit hours of graduate course work, and one semester of Graduate Seminar. Non-thesis students are encouraged to do a three-credit project under the independent study course registration. An approved study plan must include at least **12- 9** credits of 6000 level graduate course work, including the project if elected. Up to nine credit hours of graduate course work from other departments may be included among the minimum of 33 credits. A maximum of six graduate credits from other accredited graduate programs completed with a 'B' or better and not counted toward a previous degree may be included in the study plan. Transfer credits must meet university requirements. The advisor and the Graduate Coordinator must approve transfer courses if they are to be included in a study plan. A maximum of three credits of independent study beyond an independent project may be included in a study plan.

Non-thesis students are required to take a final oral comprehensive exam dealing with the objectives of their study plan. If a project has been completed, the student will briefly summarize the project report (20 minutes) as a part of the exam. The examining committee will include a minimum of three faculty members, at least two of whom should be from the department.

**Course Requirements**

All MSME degree seeking students must take **two of the following applied/computational mathematics courses offered by MME department the following two courses or equivalent plus the MME graduate seminar. one seminar as common core courses:**

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EGM 5315	Intermediate Analysis of Mechanical Systems	3
EGM 5346	Computational Engineering Analysis	3
EGM 5354	Finite Element Method Applications in Mechanical Engineering	3
EGM 6355	Nonlinear Finite Element Analysis	3
EGM 6422	Advanced Analysis of Mechanical Systems	3
EGM 6422	Advanced Computational Engineering Analysis	3
EML 6725	Computational Fluid Dynamics	3
EML 6935	Graduate Seminar	0

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An additional six credit hours of **core** courses must be taken outside the speciality of major area of the student, **depending on the area of interest.** Remaining 4 courses should in the area of student's specialization or as suggested by student's major professor and committee. A maximum of three credit hours of approved independent studies, EML 6908, may be counted towards the M.S. thesis degree.

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**Thermo/Fluid/Biomedical Area:**

EML 5709	Intermediate Fluid Mechanics	3
EML 6725	Computational Fluid Dynamics	3

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**Mechanics/Materials Area:**

EGM 5615	Synthesis of Engineering Mechanics	3
EGM 6570	Fracture Mechanics	3

**Design and Manufacturing Area:**

EML 5530	Intermediate CAD/CAE	3
EML 5385	Identification Techniques of Mechanical Systems	3

A minimum of 9 (thesis) or 18 (non-thesis) credit hours are to be taken from the following Mechanical Engineering courses. (Up to a maximum of six (thesis) or nine (non-thesis) semester hours may be taken from courses offered by other departments).

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**Thermo/Fluid/Biomedical** (Each course is 3 credits unless stated otherwise)

**EGM 6586** Fluid Mechanics Applications in Psychological Systems

**EGM 6587** Applied Biomedical & Diagnostic Measurements

**EGM 6588** Solid Mechanics Applications in Psychological Systems

EML 5103 Intermediate Thermodynamics

EML 5104 Classical Thermodynamics

EML 5152 Intermediate Heat Transfer

EML 5606C Advanced Refrigeration & A/C Systems

EML 5615C Computer Aided Design in A/C

EML 5708 Advanced Design of Thermal and Fluid Systems

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**EML 5709** Intermediate Fluid Mechanics

EML 6153C Advanced Heat Transfer

EML 6154 Conduction Heat Transfer

EML 6155 Convection Heat Transfer

EML 6157 Advanced Radiation Heat Transfer

EML 6712C Advanced Fluid Mechanics

EML 6714 Advanced Gas Dynamics

EML 6725 Computational Fluid Dynamics

**Mechanics/Materials** (Each course is 3 credits unless stated otherwise)

EGM 5346 Computational Engineering Analysis

EGM 5354 Finite Element Method Appl in ME

**EGM 5615** Synthesis of Engineering Mechanics

EGM 6570 Fracture Mechanics

EMA 5295 Principles of Composite Materials

EMA 5507C Analytical Techn. of Materials Sciences

EMA 5935 Advanced Topics in Materials Engineering

EMA 6127C Advanced Physical & Mechanical Metallurgy

EMA 6165C Polymer Physics & Analytical Techniques

EML 5505 Smart Machine Design and Development

EML 5509 Mechanical Design Optimization

EML 5125 Classical Dynamics

EML 5385 Identification Techniques of Mech. Systems

EML 5562 Advanced Electronic Packaging

EML 6223 Advanced Mech. Vibration Analysis

EML 6233 Fatigue and Failure Analysis

EML 6805 Advanced Design of Robots

### Design and Manufacturing

EML 5385 Identification Techniques of Mechanical Systems

EML 5505 Smart Machine Design and Development

EML 5509 Mechanical Design Optimization

**EML 5530** Intermediate CAD/CAE

EML 5562 Advanced Electronic Packaging

**EGM 5615** Synthesis of Engineering Mechanics

EML 5808 Control Technology for Robotic Systems

EML 5825 Sensors and Applied Machine Intelligence

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EML 6223 Advanced Mechanical Vibration Analysis

EML 6532 Advanced CAD/CAE

**EGM 6570** Fracture Mechanics

EML 6805 Advanced Design of Robots

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## Master of Science in Materials Science and Engineering (MSMSE)

### Admission Requirements

The Department of Mechanical and Materials Engineering offers both thesis and non-thesis options for the Master's Degree. A student seeking the Master's degree with or without thesis is required to pass a comprehensive oral or written examination.

All work counted for the Master's degree must be completed during the six years immediately following the date of admission.

The program provides a broad education, covering more than one field, followed by in-depth studies in areas of interest.

### Admission Requirements

The following is in addition to the University's graduate admission requirements:

1. A student seeking admission into the program must have a bachelor's degree in engineering, physical sciences, computer science or mathematics from an accredited institution, or, in the case of foreign students, from an institution recognized in its own country as preparing students for further study at the graduate level.

2. An applicant must have achieved a "B" average, GPA of 3.0 in upper level undergraduate work and a combined score of 1100 on the Graduate Record Examination with the following minimum scores on the individual components: verbal  $\geq 350$  and quantitative  $\geq 650$ .

3. Applicants who have not satisfied the above will be evaluated for probationary or waiver admission.

4. In addition to the above criteria, International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of **213 on the TOEFL**, 80 on the iBT TOEFL or 6.3 overall on the IELTS is required.

5. The GPA, GRE and TOEFL scores specified above are to be considered minimum requirements for admission. Applicants from science areas other than mechanical engineering will be expected to complete undergraduate courses selected to prepare them for graduate courses in their area of interest. Full admission to the graduate program requires the completion of these background courses with no grades below 'C' and a grade point average of 3.0 or better.

### Graduation Requirements

The degree will be conferred when the following conditions have been met:

1. Recommendation of the advisor and faculty of the Department.

2. Certification provided by the Department Chair, College Dean, and University Graduate School that all degree requirements have been met.

3. Completed the two department core course requirements plus the two required core courses in the student's major area.

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4. Completed undergraduate course **deficiencies** specified at admission, if any, with no grades below 'C' and a GPA  $\geq 3.0$ .

5. Thesis option: Successfully completed a minimum of 30 semester hours of graduate course work as specified in an approved study plan containing at least 6 hours of 6000 level courses with a GPA  $\geq 3.0$  (the minimum successful grade is a 'C'; not more than six semester hours transferred from another accredited graduate program that was not part of a previously awarded degree may be **incorporated** in the study plan) plus a minimum of six hours of masters thesis.

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Non-thesis option: Successfully completed a minimum of 27 semester hours of graduate course work as specified in an approved study plan and a 3 credit hour project with a GPA  $\geq 3.0$  (not more than six semester hours transferred from another accredited graduate program that was not part of a previously awarded degree may be incorporated in the study plan).

6. Thesis degree: Successful public oral defense of the thesis. Submission of the approved thesis to the Graduate School.

Non-thesis degree: Successful completion of a formal report and presentation.

7. Students must achieve an overall GPA  $\geq 3.0$  in all graduate work completed at FIU in their approved study plan.

8. Completed one semester of the Graduate Seminar course.

9. Complied with all relevant University policies and regulations.

**Thesis Option**

A student shall complete a minimum of 24 semester credit hours of course work, plus a minimum of 6 semester credit hours of EMA 6971, Master's Thesis, and **one semester of the MME Graduate Seminar.**

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A maximum of 6 credit hours of courses offered by other departments may be included among the 24 course hour minimum. A maximum of three credit hours of approved independent studies, EML 6908, may be counted toward the M.S. thesis degree. A maximum of six graduate credit hours can be transferred from other accredited institutions provided that the courses have not been used for another degree and have a minimum letter grade of 'B'. Transfer courses must be approved by the advisor and Graduate Coordinator.

Early in the program (before the end of the second term) the student and advisor will complete a study plan that specifies the courses that will comprise the program.

When the thesis research is completed, the student should schedule a defense with an examining committee appointed through the Graduate School consisting of a least three faculty members (at least two of whom should be from the department). The thesis, with an approval cover letter from the advisor, should be given to the examining committee for review not less than **four two** weeks before the scheduled defense. The candidate should prepare to summarize the thesis in the manner of a technical paper using appropriate visual aids in 40 minutes or less. Following the presentation, the candidate will answer questions related to the work from the audience and/or the committee. At the conclusion of the defense, the committee will agree on the outcome -pass or fail- and report the results to the Graduate School. Following the

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exam the student will implement the committee's suggestions for improving the draft document. Each committee member must sign the approval form bound in the final document. Hardcover bound copies of the approved thesis must be provided to the advisor, department, and the library.

**Non-Thesis Option**

A student shall complete a minimum of 30 semester credit hours of graduate course work, and one semester of Graduate Seminar. Non-thesis students are encouraged to do a three-credit project under the independent study course registration. Up to nine credit hours of graduate course work from other departments may be included among the minimum of 30 credits. A maximum of six graduate credits from other accredited graduate programs completed with a 'B' or better and not counted toward a previous degree may be included in the study plan. The advisor and the Graduate Coordinator must approve transfer courses if they are to be included in a study plan. A maximum of three credits of independent study beyond an independent project may be included in a study plan.

Non-thesis students are required to submit a formal report and presentation of the project, with the report and presentation evaluated by an examining committee that will include a minimum of three faculty members, at least two of whom should be from the department.

**Areas of Specialization**

- Metals and Alloys
- Electronic **Materials materials**
- Ceramics
- Polymers and Biomaterials
- Nanomaterials**

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**Course Requirements**

All MSMSE degree seeking students must take the following two courses or equivalent plus one seminar as common core courses:

EMA 5106	Thermodynamics and Kinetics of Materials	3
EMA 5001	Physical Properties of Materials	3
EML 6935	Graduate Seminar	0
Select two of the following courses with advisor approval:		
EMA 5140	Introduction to Ceramics	3
EMA 5507C	Analytical Methods in Material Science	3
EMA 6127C	Mechanical Metallurgy	3
EMA 6165C	Polymer Science	3
EMA 6399C	Electronic Properties of Material Science	3

The remainder of the courses shall be chosen from the electives with consultation of the student's advisor. Additionally, up to six hours may be taken from courses offered by other departments.

**MSMSE Elective Courses:**

EEL 6332	Thin Film Engineering	3
EML 5103	Inter. Thermodynamics	3
EMA 5xxx	Surface Science	3
EMA 5295	Principles of Composite Materials	3
EGM 5354	FEM Applications in Engineering	3
EGN 5367	Industrial Materials and Engineering Design	3
EMA 6126	Adv. Physical Matellurgy	3
EML 6233	Fatigue and Failure Analysis	3
EGM 6355	Nonlinear Finite Element Analysis	3

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	EML 6908	Independent Study	1-3
45	<del>EML 6910</del>	<del>Supervised Research</del>	<del>1-6</del>
	EML 6971	Master Thesis	1-6
	EMA 5015	Introduction to Nanomaterials Engineering	3
	EMA 5104	Adv. Mechanical Properties of Materials	3
	EMA 5016	Nanoelectronic Materials	3
	EMA 5017	Nanoparticle Technology	3
	EMA 5018	Nanoscale Modeling of Materials	3
	EMA 5646	Ceramic Processing	3
	EMA 5605	Fundamentals of Materials Processing	3
	EMA 6518	Transmission Electron Microscopy	3
	EMA 6665	Polymer Processing and Engineering	3
	EMA 6449	Electronic Properties of Ceramic Materials	3
	EMA 6264	Mechanical Properties of Polymers	3

## Doctor of Philosophy in Mechanical Engineering

### Admission Requirements

The requirements for admission to the doctoral program in Mechanical Engineering for applicants having a Bachelor's degree in Mechanical Engineering from an accredited institution are the following:

- a) GPA of at least 3.0/4.0 in the last 60 upper level credit hours
- b) GRE of at least 1120-1150 points on the verbal and quantitative sections with the following minimum on the individual components: verbal  $\geq$  450 and quantitative  $\geq$  650.
- c) Three letters of recommendation.
- d) International graduate student applicants whose native language is not English are required to submit a score for the Test of English as a Foreign Language (TOEFL) or for the International English Language Testing System (IELTS). A total score of 213 on the TOEFL, 80 on the iBT TOEFL or 6.3 overall on the IELTS is required.
- e) Applicants having a Master's degree in Mechanical Engineering from an accredited institution must also satisfy the above requirements for admissions to the doctoral program; however a GPA of at least 3.3/4.0 in the Master's program is also required.

Credentials of all other applicants will be examined by the Graduate Admission Committee on a case by case basis.

In addition to the departmental requirements, all students must satisfy the University's Graduate Policies and Procedures.

### Identification of Research Area

Within 15-4 months upon acceptance into the Ph.D. program, the student having a Master's Degree has to identify an area of research of his or her interest by contacting and being accepted by a professor willing to guide the dissertation research. The student with a Bachelor's degree should identify the area of research within 12 months upon acceptance into PhD program. If no professor is obtained, the student will be dismissed from the Ph.D. program. Contact the department for a list of the graduate faculty members and their research interests.

### Course Requirements

Applicants having a Bachelor's degree in Mechanical Engineering are required to complete at least 90-78 credit

hours, of which at least 66-54 hours must be course work and 24 hours dissertation. The credit hours earned towards the Ph.D. program have the following requirements:

1. At least 36-30 credits at the 5000 level or higher, not to include dissertation.
  2. At least 24-15 credits at the 6000 level or higher, not to include dissertation.
  3. Breadth criteria could be satisfied by taking 3 courses in a field/area outside student's own field.
  4. Two applied/computational mathematics courses as suggested for MS program.
  3. A minimum of 9 semester credits in Mathematics.
  4. A maximum of 18 credits outside the areas of Mathematics and Mechanical Engineering.
  5. A minimum of 24 credits of dissertation.
- A maximum of 6 semester hours of graduate credit earned from another accredited institution that was not used for a previous degree may be transferred as long as the courses were completed within the six years preceding admission to the program and meet university requirements.

Applicants entering the Ph.D. program with a Masters degree should meet the following requirements:

1. Breadth criteria could be satisfied by taking 3 courses in a field/area outside student's own field.
2. A minimum of 24 credits of dissertation.
3. Additional courses to be determined by candidate's dissertation committee.

Applicants having a Master's Degree in any Engineering discipline from an accredited institution may include a maximum of 30 semester hours as part of their requirements.

### Fast-Track Ph.D. Program

MSME students whose higher education goal is to receive the Ph.D. degree in Mechanical Engineering may apply for the fast-track Ph.D. program up to one semester prior to the completion of their MSME degree requirements. Application for the fast-track Ph.D. program will be evaluated and must be approved by the graduate committee and the student's advisor. If the student withdraws from this program before receiving the Ph.D. degree, the student remains eligible to receive the MSME degree provided that they fulfill all requirements for that degree. International students should consult with International Student and Scholars Services before abandoning the Ph.D. program. Students who qualify for the fast track Ph.D. option will have 6 credit hours of master's thesis waived, but the students will meet all the requirements of the Ph.D. program.

### Core Courses

**Mathematics:** 9 credit hours selected from the following list:

- MAA 4402 — Complex Variables<sup>1</sup>
- MAS 5145 — Applied Linear Algebra
- STA 5206 — Design of Experiments
- MAD 5405 — Numerical Methods
- STA 5126 — Fundamentals of Design of Experiments
- MAP 4401 — Adv. Differential Equations<sup>1</sup>
- STA 5236 — Regression Analysis
- MAP 5236 — Math. Tech. of Oper. Research

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STA 5676	Reliability Engineering
MAP 5407	Methods of Applied Analysis
STA 5800	Stochastic Proc for Engineers
STA 5505	Nonparametric Methods
STA 6166	Statistical Methods in Research I
STA 6167	Statistical Methods in Research II
STA 6176	Biostatistics
STA 6246	Data Analysis I
STA 6247	Data Analysis II
STA 6326	Mathematical Statistics I
STA 6327	Mathematical Statistics II
STA 7707	Multivariate Methods I
STA 7708	Multivariate Methods II

Other 6000 and 7000 level courses in the Mathematics and Statistics departments may also be acceptable. Check with the Graduate Program Director.

<sup>1</sup>These are the only two undergraduate courses that are allowed.

**Engineering:** 18 credit hours as listed below:

EGM 5315	Intermediate Analysis of Mechanical Systems
EGM 5615	Synthesis of Engineering Mechanics
EGM 6422	Adv. Analysis of Mechanical Systems
EMA 5935	Adv. Topics in Materials Engineering
EML 5530	Intermediate CAD/CAE
EML 5709	Intermediate Fluid Mechanics

**Dissertation:** 24 credits

**Elective Courses:** An additional 39 credit hours available to students admitted directly based on a Bachelors degree. Possible elective courses from the Mechanical Engineering department include:

**Thermo/Fluid**

EGM 6586	Fluid Mechanics Applications in Physiological Systems
EGM 6587	Applied Biomedical & Diagnostic Measurements
EGM 6588	Solid Mechanics Applications in Physiological Systems
EML 5103	Intermediate Thermodynamics
EML 5104	Classical Thermodynamics
EML 5152	Intermediate Heat Transfer
EML 5606C	Advanced Refrigeration & A/C Systems
EML 5615C	Computer Aided Design in A/C
EML 5708	Advanced Design of Thermal and Fluid Systems
EML 6153C	Advanced Heat Transfer
EML 6154	Conduction Heat Transfer
EML 6155	Convection Heat Transfer
EML 6157	Advanced Radiation Heat Transfer
EML 6712C	Advanced Fluid Mechanics
EML 6714	Advanced Gas Dynamics
EML 6725	Computational Fluid Dynamics

**Mechanics/Materials**

EGM 5346	Computational Engineering Analysis
EGM 5354	Finite Element Method Appl in ME
EGM 6570	Fracture Mechanics
EMA 5295	Principles of Composite Materials
EMA 5106	Thermodynamics and Kinetics of Materials
EMA 5001	Physical Properties of Materials
EMA 5507C	Analytical Techn. of Materials Sciences
EMA 5935	Advanced Topics in Materials Engineering

EMA 6127C	Advanced Physical & Mechanical Metallurgy
EMA 6165C	Polymer Physics & Analytical Techniques
EML 5505	Smart Machine Design and Development
EML 5509	Mechanical Design Optimization
EML 5125	Classical Dynamics
EML 5385	Identification Techniques of Mech. Systems
EML 5562	Advanced Electronic Packaging
EML 6223	Advanced Mech. Vibration Analysis
EML 6233	Fatigue and Failure Analysis
EML 6805	Advanced Design of Robots

**Design and Manufacturing**

EML 5385	Identification Techniques of Mechanical Systems
EML 5505	Smart Machine Design and Development
EML 5082	Advanced Nondestructive Testing and Mechanical Health (MME)
EML 5509	Mechanical Design Optimization
EML 5519	Fault-Tolerant System Design
EML 5562	Advanced Electronic Packaging
EML 5808	Control Technology for Robotic Systems
EML 5825	Sensors and Applied Machine Intelligence
EML 6223	Advanced Mechanical Vibration Analysis
EML 6532	Advanced CAD/CAE
EML 6805	Advanced Design of Robots

**Residency Requirements**

The program will provide student access to a wide range of support facilities including research library, cultural events, and other occasions for intellectual growth associated with campus life, significant faculty/student interaction, opportunities for student exposure to and engagement with cognate disciplines and research scholars working in those disciplines, and significant peer interaction among graduate students. Students will be provided with the opportunity for a mentoring apprentice relationship with faculty and students as well as adequate time for in-depth evaluation of the student. To satisfy the residency requirement for the Ph.D. degree, the candidate must complete a minimum of 18 credit hours within a period of 12 months at the University.

**Graduate Supervisory and Research Committee**

The student's Ph.D. Graduate Supervisory and Research Committee should be appointed as soon as possible and no later than 45.4 months after being admitted to the Ph.D. program. Consult the Graduate Guidelines in the department for more details on how to select the committee members.

**Ph.D. Course Breadth Requirements**

Breadth criteria could be satisfied by taking 3 courses in a field/area outside student's own field.

**Examinations and Proposal and Final Defense**

Student must demonstrate graduate knowledge acquisition in four incremental stages in order to be awarded a Ph.D. in Mechanical Engineering. Stage I - Qualifying Exam (QE)

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Stage II - Proposal Defense (Graduate Seminar)

Stage III - Comprehensive Exam (CE) which is the PhD

Candidacy Examination

Stage IV - Final Defense

In the semester prior to his/her taking the QE or CE, student must declare intention to take QE or CE and must declare a major field or area of research.

### I. Qualifying Exam (QE)

General written exam to test masters level knowledge.

A student who is admitted to the Ph.D. program with a bachelors degree must take the QE no later than the beginning of the 4th major semester 3rd year after admission, and a student who enters the Ph.D. program with a masters degree must take and pass the QE no later than the beginning of the 2nd major semester 2nd year after admission. Students may petition for exceptions from the departmental graduate student committee by one major semester at a time. A student who fails the QE may retake the exam once only.

### II. Proposal Defense (PD)

The dissertation proposal will be presented by the student in the form of a Graduate Seminar in which he/she must submit a proposal for his/her dissertation.

Students must declare their proposal subject after taking the Qualifying Exam but before taking the Comprehensive Exam.

### III. Comprehensive Exam (CE) Candidacy Examination

The objective of the CE is to assess the depth of knowledge in the major field of research. The examination will be developed by the student's dissertation committee. It must be taken before the end of the 2nd semester of Year 3.

### IV. Final Defense (FD)

There will be a public defense at a graduate seminar. The defense can be failed no more than twice.

The final defense should be presented no later than the 4th year after the master's degree and no later than the 6th year after the bachelor's degree.

Following the successful defense of the dissertation, as determined by a majority vote of the student's examining committee, the dissertation must be forwarded to the Dean of the College of Engineering and Computing and the Dean of the University Graduate School for their approval.

All dissertations submitted in fulfillment of the requirements for graduate degrees must conform to University guidelines (see "Regulations for Thesis and Dissertation Preparation"). One final and approved copy of the dissertation must be delivered to the Chairperson of the Department of Mechanical Engineering and one to the advisor. Library copies must conform to University guidelines, also published in "Regulations for Thesis and Dissertation Preparation."

### Financial Aid

Consult the Department for information on research and teaching assistantships available for doctoral students.

## Course Descriptions

### Definition of Prefixes

EAS – Engineering; Aerospace

EGM – Engineering; Mechanics

EGN – Engineering; General

EMA – Engineering; Materials

EML – Engineering; Mechanical

### EAS 5124 Aerodynamics and Flight Mechanics (3).

Fundamentals of aerodynamics, definition of aerodynamic shapes, analysis of aerodynamic forces, airplane performance, and flight stability and control. Prerequisites: EGN 3321, EML 3126, EGN 3343.

**EAS 6185 Turbulence (3).** Fundamentals of turbulent flow, solutions for bounded and free turbulent flows, dynamics of turbulence, statistical description of turbulence, spectral dynamics, and stability.

**EGM 5315 Intermediate Analysis of Mechanical Systems (3).** First course at the graduate level in the analysis of mechanical systems. Modeling of the system and analytical and numerical methods of solution of the governing equations will be studied. Fluid and thermodynamic systems will be emphasized in this course. Prerequisites: EGM 3311 or permission of the instructor.

### EGM 5346 Computational Engineering Analysis (3).

Application of computational methods to mechanical engineering problems of translational, rotational, control, thermal and fluid systems employing linear/nonlinear system elements. Prerequisites: EML 2030 or CGS 2420 or CGS 2423, MAP 2302 or EGM 3311, and EML 3222, or permission of the instructor.

### EGM 5354 Finite Element Method Applications in Mechanical Engineering (3).

Utilize the finite element method to solve problems in heat transfer, fluid dynamics, diffusion, acoustics, vibration, and electromagnetism, as well as the coupled interaction of these phenomena. Prerequisites: EML 2030 or CGS 2420, EMA 3702, and EML 4140.

~~**EGM 5585 Biotransport Processes (3).** Transport of fluid, heat, and mass in the human body. Application to dialyzers and heart lung devices. Prerequisites: EML 3126L and EML 4140.~~

### EGM 5615 Synthesis of Engineering Mechanics (3).

Unified approach to the analysis of continuous media using constitutive equations, mechanical behavior of materials and their usefulness in handling failure theories and composite materials. Prerequisites: MAP 2302 or EGM 3311, and EMA 3702.

### EGM 5935 Review of Topics in Mechanical Engineering (4).

To prepare qualified candidates to take Mechanical Engineering PE written examination. Reviewed courses include Thermodynamics, Fluid Mechanics, Mechanics of Materials, Mechanical Design and Heat Transfer.

### EGM 6355 Nonlinear Finite Element Analysis (3).

Nonlinear finite element analysis. Geometric and material nonlinearities will be considered in the formulation of different finite elements. Prerequisite: Permission of the instructor.

~~**EGM 6422 Advanced Computational Engineering Analysis (3).** Advanced Analysis of Mechanical Systems (3).~~ Modeling of vibrational and dynamic systems including solution of governing equations by analytical and numerical techniques. Prerequisites: EGM 5315 or permission of the instructor.

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**EGM 6455 Impact Dynamics (3).** Mechanical impact, point-mass collisions, vibratory impact, stress waves in solids, elastic-plastic stress waves, low velocity impact, penetration and perforation applications. Prerequisites: EGN 3321 and EMA 3702.

**EGM 6570 Fracture Mechanics (3).** Griffith's and Irwin's fracture criteria; stress intensity factors evaluation; crack-tip plastic zone; fracture toughness measurement; crack initiation; fatigue crack growth; stress corrosion cracking. Prerequisite: EGM 5615.

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**EGM 6586 Fluid Mechanics Applications in Physiological Systems (3).** Fluid mechanics principles including finite element and finite difference methods as it is applied to the analysis of various physiological systems will be covered. Process flow, diffusion and transport will be discussed in cardiovascular and pulmonary systems. Application of these primarily in the design of heart-lung machines, dialysis units, and heart valves will be discussed. Prerequisites: EGM 4580 or permission of the instructor.

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**EGM 6587 Applied Biomedical and Diagnostic Measurements (3).** Fundamentals of biomedical measurements and the design of biomeasurement systems and devices. This includes transducers and electrodes, EMG, EEG, ECG and medical imaging techniques, and electrical safety. Prerequisites: EGM 4580 or permission of the instructor.

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**EGM 6588 Solid Mechanics Applications in Physiological Systems (3).** Solid mechanics and numerical methods as applied to rheology analysis of the musculoskeletal system and trauma. Design application in orthotics and prosthesis and heart valves. Prerequisites: EGM 4580 or permission of the instructor.

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**EGM 6589 Advanced Biofluid Mechanics (3).** Applications of fluid mechanics principles to human circulatory systems. Unsteady blood flow and wave propagation in elastic tubes. Influence of fluid dynamics on thrombosis and atherosclerosis. Prerequisite: EGM 6586.

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**EGM 6593 Advanced Cardiac Mechanics (3).** Applications of principles of solid mechanics to the human cardiovascular system. 3D reconstruction of the left ventricle, contractile properties and stress distribution in the myocardium. Prerequisite: EGM 6588.

**EGM 6654 Advanced Theory of Elasticity (3).** Modern methods of stress and strain analysis including two-dimensional problems of stress concentration, contact adhesion, friction, thermal stresses, and dynamic waves. Prerequisites: EGM 5615, EGM 5315, or permission of the instructor.

**EGM 7456 Advanced Impact Dynamics (3).** High velocity impact mechanics, hyper velocity impact mechanics, penetration mechanics, long rod and plate penetration mechanics, dynamic fracture, kinetic energy penetration, analytical modeling. Prerequisites: EML 6455 and permission of the instructor.

**EGM 7574 Advanced Fracture Mechanics (3).** Modern fracture mechanics including invariant integrals, nano-scale fracture, environmental fracture, penetration mechanics, failure waves, erosion, and fracture by electron and laser beams. Prerequisites: EGM 6570, EGM 6422.

**EGM 7575 Cutting Mechanics (3).** Study of cutting stress, impact stress, stress and strain waves, tensile failure, shear-tension couples, responses in cutter and material, mechanics in body, fiber and molecular structures. Prerequisites: EML 6455 and permission of the instructor.

**EGM 7676 Classic Topics of Nonlinear Mechanics (3).** Classic topics on nonlinear mechanics, such as Theory of Plasticity of Solids, and the Theory of Jets and Cavities of Fluids. Prerequisites: EGM 5315, EGM 6422, EGM 5615, EML 5709.

**EGN 5367 Industrial Materials and Engineering Design (3).** Industrial materials, material selection, and engineering design process, including synthesis, analysis, optimization, and evaluation.

**EMA 5001 Physical Properties of Materials (3).** The physical properties of materials, including the influence of structure on properties, thermodynamics of solids and phase transformations and kinetics on microstructural development. Prerequisite: EGM 4521C.

**EMA 5015 Introduction to Nanomaterials Engineering (3).** The science and engineering of nanomaterials, the fabrication, behavior, and characterization of the nano-size particles and materials. Prerequisites: EGN 3365, EGM 3311.

**EMA 5016 Nanoelectronic Materials (3).** Course provides an understanding of nanotechnology based on materials engineering. Topics include energy bands in semiconductors, MOSFET scaling, materials processing and other applications. Prerequisite: EGN 3365.

**EMA 5017 Nanoparticle Technology (3).** An interdisciplinary overview of the nanoparticle engineering. Synthesis of nanoparticles, nanoparticle growth and transport, characterization methods, and applications. Prerequisites: EGN 3365 or permission of the instructor.

**EMA 5018 Nanoscale Modeling of Materials (3).** Overview of computational nanotechnology. Modeling, simulation and design of nanomaterials. Energy minimization, molecular dynamics and advanced multiscale numerical techniques. Prerequisites: EGN 3365 or permission of the instructor.

**EMA 5104 Advanced Mechanical Properties of Materials (3).** Advanced treatment of the mechanical behavior of solids; examines crystal plasticity, dislocations, point defects and grain boundaries, creep and fatigue behavior, fracture. Prerequisite: EGM 3311 Analysis of Mechanical Systems (3).

**EMA 5106 Thermodynamics and Kinetics of Materials (3).** Laws of thermodynamics. Entropy and free energy. Diffusion mechanisms. Transition state theory and field effects. Phase diagrams. Nucleation in condensed phases. Crystal growth. Prerequisite: EGN 3343 Thermodynamics I.

**EMA 5140 Introduction to Ceramic Materials (3).** Synthesis of ceramics, inorganic glasses and their microstructure as related to physical properties. Prerequisites: EGN 3365 or instructor's permission.

**EMA 5295 Principles of Composite Materials (3).** The mechanical behavior of composite materials used in the

automotive, aircraft and sporting goods industries; material and laminar properties; design of composites; failure analysis; and environmental effects. Prerequisites: EGM 5615 or permission of the instructor.

**EMA 5507C Analytical Techniques of Materials Science (3).** Fundamental theories and techniques of the analytical methods for materials including: X-ray diffraction, scanning and transmission electron microscopy, thermal and surface analysis, and vacuum systems. Prerequisite: EGN 3365.

**EMA 5584 Biomaterials Science (3).** Materials used in prostheses for skin and soft tissue, vascular implant devices, bone repair, and artificial joints. Structure-property relationships for biological tissue. Prerequisites: EGN 3365 and EMA 3702.

**EMA 5605 Fundamentals of Materials Processing (3).** Extraction of materials from the minerals using pyro, hydro and electro techniques. Fundamentals of solidification process. Prerequisites: MSE 4521 or permission of the instructor.

**EMA 5646 Ceramic Processing (3).** Introduction to the science of ceramic processing, with emphasis on the theoretical fundamentals and current state-of-the-art processing. Prerequisite: EMA 5140.

**EMA 5935 Advanced Topics in Materials Engineering (3).** Topics include thermodynamics of solids, principles of physical metallurgy, including phase transformation and diffusion and analytical methods in materials engineering. Prerequisites: EGN 3365 and EGM 3343.

**EMA 6126 Advanced Physical Metallurgy (3).** Energetics of phase transformation and spinodal decomposition, homogeneous and heterogeneous nucleation in solid state reactions, and martensite transformations. Prerequisites: EMA 4121 or permission of the instructor.

**EMA 6127C Advanced Physical and Mechanical Metallurgy (3).** Advanced topics in physical and mechanical metallurgy including statics and dynamics of dislocations, plastic deformation of fracture, creep solidification, phase transformation, and heat treatment. Prerequisites: EGN 3365 or permission of the instructor.

**EMA 6165C Polymer Physics and Analytical Techniques (3).** Topics in polymers and the analytical techniques, including: synthesis, characterization, state of polymers, plasma processes, X-ray diffraction, scanning and transmission electron microscopy. Prerequisites: EGN 3365 or permission of the instructor.

**EMA 6185 Advanced Mechanics of Composite Materials (3).** Study of micromechanics and mechanical processes in microscale, including fracture, reinforcement and delamination. Prerequisite: EMA 5295.

**EMA 6264 Mechanical Properties of Polymers (3).** Advanced concepts of solid mechanics and mechanical behavior of polymers; stress-strain relationships, stress transformation, beam bending, elasticity, plasticity and fracture. Prerequisites: EMA 6165C or permission of instructor.

**EMA 6449 Electronic Properties of Ceramic Materials (3).** The defect solid state and its relation to electrical

properties of ceramics. Solid electrolytes. Theory of electron transport in metallic, semiconducting and insulating ceramics. Prerequisite: EMA 5140.

**EMA 6516 Crystallography and X-ray Diffraction (3).** Principles of crystallography and the use of x-ray diffraction and Raman Spectroscopy to characterize crystalline solids. Prerequisite: Instructor's permission.

**EMA 6518 Transmission Electron Microscopy (3).** Kinematic and dynamic theories of diffraction contrast and electron interaction in materials. Diffraction analysis for structural and compositional determination. Specimen preparation techniques. Prerequisite: EMA 5507.

**EMA 6665 Polymer Processing and Engineering (3).** Standard and advanced processing methods, characterization of morphology, and reaction processing. An industry-based case study analysis integrates heat and mass transport, and fluid flow during materials processing; and the economics of materials processing and recycling. Prerequisite: Permission of instructor.

**EMC 5415 Digital Control of Mechanical Systems (3).** Discrete modeling of mechanical systems. Digital feedback systems. Computer interface of mechanical systems. Controller design with emphasis on hydraulic, pneumatic and electromechanical devices. Prerequisite: EML 4312.

**EML 5XXX Professional Development and Leadership for Mechanical Engineers (3).** Consequences of engineering and concepts of personal career management, decision making, leadership and intrapreneuring that enhance the effectiveness of professional engineering practice. Prerequisite: Senior standing in engineering.

**EML 5XXX Special Projects in Mechanical Engineering Design and Business Development (3).** Mechanical engineering design project that encompasses conceptual and structural design, analysis and optimization complemented by a study to develop a business venture to produce the designed product. Prerequisites: EML 4501 or equivalent, QMB 6357, and MAN 6209.

**EML 5082 Advanced Nondestructive Testing and Mechanical Health Monitoring (3).** Theory and application of Nondestructive Testing (NDT) and Mechanical Health Monitoring (MHM) techniques will be discussed. Automated interpretation of signals and advanced methods will be presented. Prerequisite: Permission of the instructor.

**EML 5103 Intermediate Thermodynamics (3).** Thermodynamic approach to processes and engines; alternative formulations and legendre transformations; maxwell relations, first and second order phase transitions. Prerequisite: EML 3101.

**EML 5104 Classical Thermodynamics (3).** Mathematical analysis of the laws of classical reversible and irreversible thermodynamics. Applications to mechanical, electromagnetic, and chemical systems, under ideal and real conditions. Prerequisite: EML 3101.

**EML 5125 Classical Dynamics (3).** Kinematics of rigid body motion, Eulerian angles, lagrangian equations of

motion, inertia tensor, momental ellipsoid. Rigid-body equations of motion, Euler's equations, force-free motion, polhode and herpolhode, theory of tops and gyroscopes. Variational principles. Hamiltonian equations of motion. Poincaré representation. Prerequisites: MAP 2302 or EGM 3311, and EGN 3321.

**EML 5152 Intermediate Heat Transfer (3).** Multi-dimensional heat conduction under steady and transient conditions. Heat, mass and momentum transfer. Radiation heat transfer. Gas radiation. Free and forced convection. Prerequisite: EML 4140.

**EML 5385 Identification Techniques of Mechanical Systems (3).** FFT, time series analysis and neural networks are introduced. Applications of these techniques are discussed for identification of mechanical structures, and machine diagnostics. Prerequisite: EML 4312.

**EML 5412 Combustion Processes (3).** Introduction to combustion processes, thermochemistry, chemical kinetics, laminar flame propagation, detonations and explosions, flammability and ignition, applications in IC engines and gas turbines. Prerequisites: EML 3101 and EML 4140.

**EML 5505 Smart Machine Design and Development (3).** Design of independently operating smart electro-mechanical systems (most consumer products) which monitor their environment, give decisions, and create motion. Prerequisites: EML 4312 or consent of instructor.

**EML 5509 Mechanical Design Optimization (3).** Finite element analysis and sensitivity analysis combined with numerical optimization techniques to optimize the design. Prerequisites: EGM 5354 or permission of the instructor.

**EML 5519 Fault-Tolerant System Design (3).** Fault tolerance in mechanical, manufacturing, computer, and aerospace systems. Basic stages of fault isolation. Fault tolerance measures, architectures, and mechanical system design methodologies. Prerequisite: EML 3500.

**EML 5530 Intermediate CAD/CAE (3).** Computer aided geometrical modeling of spatial mechanical systems. Design criteria and analytical approaches for planar kinematic systems will be emphasized. Prerequisites: EML 4535 or permission of the instructor.

**EML 5562 Advanced Electronic Packaging (3).** Advanced topics in electronic packaging. Evaluation of first through fourth level assembly. Applications of computer layout design, thermal management and mechanical stability analysis. Prerequisites: EML 4561 or permission of the instructor.

**EML 5599 Heat Pipe Theory and Applications (3).** Heat pipe theory, heat pipe design and its applications, especially in the areas of energy conversion and conservation. Prerequisites: EML 3101 and EML 4140.

**EML 5606C Advanced Refrigeration and Air Conditioning Systems (3).** The various methods used in the thermal design and analysis of both refrigeration and heat pump systems are investigated. Various methods of producing heating and cooling are examined including vapor compression, absorption, air cycle, steam jet, thermoelectric, solar heating and cooling systems. Prerequisite: EML 4601.

**EML 5615C Computer/Aided Design in Air Conditioning (3).** Software will be used to demonstrate heating, ventilating and air conditioning design concepts and sizing equipment and determining performance parameters. Project design is required. Prerequisites: EML 2030 or CGS 2420 or CGS 2423, and EML 4601.

**EML 5708 Advanced Design of Thermal and Fluid Systems (3).** Advanced design of pumps, compressors, heat exchangers, HVAC systems and thermal and fluid control devices. Prerequisite: EML 4706.

**EML 5709 Intermediate Fluid Mechanics (3).** Basic concepts and scope of fluid dynamics; non-inertial reference frames. Two-dimensional potential theory. Applications to airfoils. The Navier-Stokes equations; selected exact and approximate solutions. Prerequisite: EML 3126.

**EML 5748 Boundary Layer Theory (3).** Advanced fluid dynamic analysis of the Navier - Stokes equation using boundary layer assumptions. Focus will be on solutions of thermal and fluid boundary layers. Prerequisite: EML 3126.

**EML 5808 Control Technology for Robotic Systems (3).** State-space equations of robots. Controller design based on linearization, nonlinearity cancellation, optimal control, adaptive control and other methods. Stability analysis, performance comparison. Prerequisites: EGN 3321, EML 4312 or equivalent.

**EML 5825 Sensors and Applied Machine Intelligence (3).** Sensors, signal analysis techniques, and error compensation methods will be introduced for machine intelligence. Production Machine Modeling and Design. Prerequisites: EML 4312 or permission of the instructor.

**EML 6148 Microscale Transport Phenomena (3).** Transport phenomena in small length and time scales are studied. Deviations from classical behavior are addressed. Applications include heat transfer in electronics, MEMS, and laser machining. Prerequisites: EML 5152, EML 5709, or permission of the instructor.

**EML 6153C Advanced Heat Transfer (3).** Review of analogies among heat, mass and momentum transfer. Free and forced convection from theoretical and experimental viewpoint for laminar and turbulent flows. Film and dropwise condensation. Prerequisite: EML 5152.

**EML 6154 Conduction Heat Transfer (3).** Heat transfer by conduction for steady and unsteady one and multidimensional systems with and without heat generation. Temperature distribution analysis using analytical and computational methods. Prerequisite: EML 4140.

**EML 6155 Convection Heat Transfer (3).** Development and solution of governing equations of parallel flows, boundary layer flows, instability and turbulence with convective heat transfer. Prerequisite: EML 4140.

**EML 6157 Radiation Heat Transfer (3).** Heat transfer by radiation for steady and unsteady one and multi-dimensional systems. Radiation parameters effecting different systems will be studied, analytically or numerically. Prerequisite: EML 4140.

**EML 6223 Advanced Mechanical Vibration Analysis (3).** Multidegree of freedom systems, discrete and

continuous systems; vibration control and introduction to vibration of non-linear systems. Prerequisite: EML 4220.

**EML 6233 Fatigue and Failure Analysis (3).** A study of the theoretical and practical aspects of material failure including failure modes, life prediction, corrosion with the goal of designing a safe product. Prerequisite: EGM 5615.

**EML 6518 Advanced Modeling in Mechanical Engineering (3).** Basic principles of mathematical modeling following a variety of problems in mechanical engineering. Prerequisites: EGM 6422 and EGM 5615.

**EML 6532 Advanced Computer-Aided Design/Computer-Aided Engineering (3).** Advanced CAD techniques in design of mechanical systems. Architecture of CAD systems including database applications. Advanced computational geometry student programming. Prerequisite: EML 5530.

**EML 6574 Advanced Mechanical Design Optimization (3).** Advanced topics in numerical optimization, sensitivity analysis, approximation techniques and shape optimization. Prerequisite: EML 5509.

**EML 6712C Advanced Fluid Mechanics I (3).** Turbulent flows with emphasis on engineering methods. Momentum, energy, and species transfer. Production, dissipation, and scaling laws for turbulence. Mixing length, effective viscosity. Prerequisite: EML 5709.

**EML 6714 Advanced Gas Dynamics (3).** Thermodynamic and fluid mechanics principles applied to high speed flows. Flows to be studied include flows with friction and heat loss/addition. Prerequisite: EML 4711.

**EML 6725 Computational Fluid Dynamics (3).** Basic computational methods for incompressible and compressible flows. Methods for solving the stream function equation. Boundary conditions for vorticity and stream function equations. Finite difference and finite element techniques. Prerequisites: CGS 2420, EML 6712.

**EML 6747 Mechanics of Fluid Flow in Porous Materials (3).** The mathematical theory of fluid penetration through porous materials and lungs, heat transfer, fluidized beds, non-stationary flows, and double continua. Prerequisite: EML 5709.

**EML 6750 Multiphase Suspension Flow (3).** Definition of multiphase flow, experimental observation, mathematical modeling of multiphase systems, measurement techniques, suspension boundary layer flow, and fluidization techniques. Prerequisite: Permission of the instructor.

**EML 6805 Advanced Design of Robots (3).** Kinematic analysis of mechanisms and robot arms, geometric configurations, analytical and numerical methods in kinematics. Prerequisites: EML 3222, EML 3262, and EML 4501.

**EML 6908 Independent Studies (1-3).** Individual research studies available for qualified graduate students. The work is to be performed under the supervision of an advisor. A report is to be submitted. Students may register for 1 to 3 credits per semester. Prerequisite: Advisor's permission.

**EML 6910 Supervised Research (1-6).** Graduate level research carried out under the supervision of a faculty member.

**EML 6935 Graduate Seminar (0).** Different problems in Mechanical Engineering and results of ongoing research will be presented and discussed by invited experts. The seminar will expose the students to advances in existing and emerging areas of research. Prerequisite: Graduate standing.

**EML 6946 Mechanical and Materials Engineering Internship (1).** Graduate students gain work experience through supervised internship in industry. The student prepares internship program proposal, and the work performed is documented in a report and presented. Prerequisite: Permission of the student's thesis advisor.

**EML 6971 Masters Thesis (1-6).** Masters thesis in any advanced topic, a report is to be submitted and an oral presentation is to be made. Students may register for one to six credits per semester. Total of six credits to be earned for the Master's Degree. Prerequisite: Advisor's permission.

**EML 7728 Mechanics of Vortex and Separated Flows (3).** Prediction of drag and lift forces acting upon a body moving in fluid or gas for large Reynolds' numbers using numerical experiments with vortex and/or separated flows. Prerequisites: EML 6712, EGM 6422, and EML 6714.

**EML 7837 Boundary Value Problems in Engineering (3).** Analytical methods and skills for closed-form solutions of boundary value problem of mathematical physics and mechanics for engineering applications based on Riemann theory. Prerequisites: MAP 5407, MAA 4402, or permission of the instructor.

**EML 7939 Ph.D. Seminar (0).** Various subjects in Mechanical Engineering and results of ongoing research will be presented and discussed by invited experts. The seminar will expose the students to advance in existing and emerging areas of research. Prerequisite: Ph.D. students only.

**EML 7979 Dissertation (3-12).** Doctoral research leading to Ph.D. Mechanical engineering dissertation. Prerequisites: Permission of Major Professor and Doctoral Candidacy.

### Justification for Changes in MME Graduate Catalog

- 1-6: Updates in title of different faculty members.
- 7: Typographical correction.
- 8: Mechanics is one of the specialization area but was not included in earlier version.
- 9: Biomedical Engineering specialization has been deleted as BME is a separate department and no more a part of MME. However "Biomechanics" specialization has been added to reflect the reserch interests and expertise in MME.
- 10: "Plasma materials processing" has been added as specialization as a new plasma lab has been established in MME.
- 11-12: Nanomaterials is one of the area of specialization in MME department.
- 13: Nanofabrication facility has been installed in AMERI. This addition refelcts new research and teaching facilities.
- 14: Cardiovascular institute has been deleted as it is a part of BME department.
- 15: HCET has been re-named as ARC. The change in name has been reflected.
- 16: The addition of new computational laboratory (MAIDROC) for large scale computing has been established in MME.
- 17: The description about "Graduate Certificate Program in Mechanical Engineering" has been added.
- 18: TOEFL score requirement was missing in the earlier version of the catalog.
- 19-20: Reflects the new requirement as established by MME department.
- 21: Typographical correction.
- 22-23: All MME graduate students are expected to attend MME Graduate seminar for their entire period of graduate program and not just for one semester. This change has been made in the new catalog.
- 24: To remove the incosistency about requirement of 6000 level credits for non-thesis option.
- 25: Reflects the new requirement for MS (ME) core courses as established by MME department.
- 26: EGM 6422 course has been renamed as Advanced Computational Engineering Analysis.
- 27: EGM 6355 and EGM 6725 have been added to list of core courses as established by MME department.
- 28: Reflects the new requirement for MS (ME) core courses as established by MME department.
- 29: Reflects the new requirement for MS (ME) as established by MME department.
- 30: Biomedical has been deleted as BME is a separate department.
- 31: These courses are offered by BME depratment with a BME prefix. Hence, deleted from MME catalog.
- 32: EML 5709 which was core course for Thermo/Fluid stem has been included in the comprehensive course list for the same stem.
- 33: EGM 5615 which was core course for Mechanics/Materials stem has been included in the comprehensive course list for the same stem.
- 34: EML 5530 which was core course for Design/Manufacturing stem has been included in the comprehensive course list for the same stem.
- 35: EGM 5615 has been included as one of the elective courses in comprehensive list of Design/Manufacturing stem.

- 36: EGM 6570 has been included as one of the elective courses in comprehensive list of Design/Manufacturing stem.
- 37: TOEFL score requirement was missing in the earlier version of the catalog.
- 38: Typographical correction.
- 39: Typographical correction.
- 40: All MME graduate students are expected to attend MME Graduate seminar for their entire period of graduate program and not just for one semester. This change has been made in the new catalog.
- 41: The usual practice of submitting the thesis to the examining committee for review two weeks before the scheduled defense has been reflected in the catalog.
- 42: Typographical correction.
- 43: Nanomaterials is one of the area of specialization in MME department.
- 44: EML 6910 Supervised Research is taken by PhD students prior to their dissertation credit registration. Hence it is deleted from MS MSE elective course list.
- 45: Several new courses were created and approved by Curriculum committee. The new course numbers have also been obtained. These courses are listed in the catalog.
- 46: Current GRE requirement for PhD admission in 1150 and not 1120. This change is made in catalog.
- 47: TOEFL score requirement was missing in the earlier version of the catalog.
- 48-60: The credit requirement for PhD program (after bachelor degree) has been reduced to 78 from 90. To accommodate this changes, several changes have been made in course requirements.
- 61: Under the new rules of reduction in credits for PhD, "Fast Track PhD Program" has become irrelevant and has been deleted from the catalog.
- 62: The credit requirement for PhD program (after bachelor degree) has been reduced to 78 from 90. To accommodate this changes, several changes have been made in course requirements.
- 63: These courses are offered by BME department with a BME prefix. Hence, deleted from MME catalog.
- 64-66: EMA 5935 course was designed when there was no "Materials" program. Now the course has become irrelevant as specific courses in Materials Science and Engineering are offered in MME. EMA 5106 and 5001 are suitable replacements for EMA 5935.
- 67: EML 5082 is the new course in Design and Manufacturing stem. The new course number has been obtained and listed in the catalog.
- 68: EML 5519 is the new course in Design and Manufacturing stem. The new course number has been obtained and listed in the catalog.
- 69-72: The credit requirement for PhD program (after bachelor degree) has been reduced to 78 from 90. To accommodate this changes, several changes have been made in course requirements.
- 73: EGM 5584 has been deleted. This course is offered by BME department with a BME prefix. Hence, deleted from MME catalog.
- 74: EGM 6422 course has been renamed as Advanced Computational Engineering Analysis.
- 75-80: These courses are offered by BME department with a BME prefix. Hence, deleted from MME catalog.
- 81: EML 5xxx: Professional Development and Leadership for Mechanical Engineers is a new course in MME department. The course has been approved by Curriculum committee. The course number is awaited.
- 82: EML 5XXX Special Projects in Mechanical Engineering Design and Business Development Engineers is a new course in MME department. The course has been approved by Curriculum committee. The course number is awaited.