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.

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

- Mechanical Systems
- Mechanics
- Robotics and Mechatronics
- Thermo/fluid Systems
- Heating-Ventilation-and-Air-Conditioning (HVAC)
- Material Characterization
- Manufacturing and Automation Systems
- Materials Science and Engineering
- Multidisciplinary Design Optimization and Inverse Design
- Computational Analysis and Distributed Parallel Computing
- Biomechanics
- Laser and Plasma Materials Processing
- Nanomaterials
- Nanotechnology
- Electronic Packaging
- Optical Measurement and Diagnostics
- Waste Management
- Renewable Energy

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 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.

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.

The Center for the Study of Materials under Extreme Conditions (CeSMEC): The center focuses on study of physical property and synthesis of materials at extreme conditions of pressure, temperature and size. The center is equipped with state of the art facilities in X-ray diffraction, spectroscopy, thermodynamic and first principle computations. Recent additions are hydride synthesis and diamond-growth facilities.

Multidisciplinary Analysis, Inverse Design, Robust Optimization and Controls (MAIDROC) Laboratory: It has a 280-processor parallel computer running Linux and MPI. MAIDROC provides independent, secure, and up-to-date computing environment for diverse large-scale simulation and design projects involving several engineering disciplines such as fluid dynamics, solid

mechanics, heat transfer, electro-magnetics and chemistry.

Graduate Certificate in Mechanical Engineering

The Graduate Certificate in Mechanical Engineering is open to degree-seeking students, non-degree seeking students, and professional 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 a 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 19 credit hours, (6 three-credit courses and a one credit capstone course, EML 6908, Independent Studies) must be completed with a GPA of 3.0 or better to receive the Graduate Certificate in Mechanical Engineering. Two of the courses (six-credits) are core courses and must be taken by all students. The remaining four courses (twelve credits) may be selected from one of two concentration areas or a combination thereof to suit the needs of the student/professional engineer.

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 concentration 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 5509	Optimization Algorithms	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
EAS 5221	Design and Analysis of Aerospace Structures	3

(2) Thermo-Fluids Area:

EML 5103	Intermediate Thermodynamics	3
EML 5152	Intermediate Heat Transfer	3
EML 5606C	Advanced Refrigeration and AC Systems	3
EML 5709	Intermediate Fluid Mechanics	3
EML 5725	Computational Fluid Dynamics	3
EAS 6721	Advanced Aerodynamic Shape Design	3

Capstone course EML 6908 Independent Studies (1 credit) must be taken as a project course and in the last semester of the certificate program.

Master of Science in Mechanical Engineering

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.
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 80 on the iBT TOEFL (equivalent to 550 on the paper-based version, or 213 on the computer-based version of the Test of English as a Foreign Language) or 6.5 overall on the IELTS is required.
5. The GPA 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.Sc. 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 the two applied/computational mathematics courses offered by the department, two courses outside student's major area and other courses as suggested by the student's major professor and committee.
4. Completion of undergraduate course deficiencies specified at admission, if any, with no grades below 'C' and a GPA ≥ 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 ≥ 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 research.
6. Non-thesis option: Successfully completed a minimum of 30 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 ≥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).
7. Thesis option: Successful public oral defense of the thesis. Submission of the approved thesis to the Graduate School.
8. Non-thesis option: Successful completion of a final oral comprehensive examination covering the general objectives of the study plan.
9. Students must achieve an overall GPA ≥ 3.0 in all graduate work completed at FIU in their approved study plan.
10. Students must complete the Graduate Seminar course.
11. 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.

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 graduate 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 in the final document. Copies of the approved thesis must be provided to the advisor, department, and the library. Students should become familiar with the University Graduate School's regulations and deadlines available on line at **http://gradschool.fiu.edu**.

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. An approved study plan must include at least 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 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. 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 thesis option students must take two of the following applied/computational mathematics courses offered by MME department plus the MME graduate seminar.

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 Computational Engineering Analysis	3
EML 6725	Computational Fluid Dynamics	3
EML 6935	Graduate Seminar	0

An additional six credit hours of courses must be taken outside the major area of study of the student. The

remaining 4 courses should in the area of the student's specialization or as suggested by the student's major professor and committee. Out of 24 semester credit hours of course work a maximum of three credit hours of approved independent studies, EML 6908, may be counted towards the M.S. thesis degree. A minimum of 6 credits of EML 6971 Thesis is also required.

All MSME degree seeking non-thesis option students must take two of the following applied/computational mathematics courses offered by MME department plus the MME graduate seminar.

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 Computational Engineering Analysis	3
EML 6725	Computational Fluid Dynamics	3
EML 6935	Graduate Seminar	0

An additional six credit hours of courses must be taken outside the major area of study of the student. The remaining 6 courses should in the area of the student's specialization or as suggested by the student's project professor; one of those courses must be EML 6908 where the students will present their project work. Out of 30 semester credit hours of course work a maximum of six credit hours of approved independent studies, EML 6908, may be counted towards the M.S.

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

EAS 6721	Advanced Aerodynamic Shape Design
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 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)

EAS 5221	Design and Analysis of Aerospace Structures
EGM 5346	Computational Engineering Analysis
EGM 5354	Finite Element Method Applications in Mechanical Engineering
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	Optimization Algorithms
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

EAS 5221	Design and Analysis of Aerospace Structures
EML 5385	Identification Techniques of Mechanical Systems
EML 5505	Smart Machine Design and Development
EML 5509	Optimization Algorithms
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
EML 6223	Advanced Mechanical Vibration Analysis
EML 6532	Advanced CAD/CAE
EGM 6570	Fracture Mechanics
EML 6805	Advanced Design of Robots

Combined BS/MS in Mechanical Engineering

Students, who pursue a BS degree and are in their junior year, with at least a 3.20 GPA on both overall and upper division courses may apply to enroll in the combined BS/MS program. To be considered for admission to the combined bachelor's/master's degree program, students must have completed at least 75-90 credits in the bachelor's degree program at FIU and meet the admissions criteria for the graduate degree program to which they are applying. Students need only apply once to the combined degree program, but the application must be submitted to Graduate Admissions before the student starts the last 30 credits of the bachelor's degree program. A student admitted to the combined degree program will be considered to have undergraduate status until the student applies for graduation from their bachelor's degree program. Upon conferral of the bachelor's degree, the student will be granted graduate status and be eligible for graduate assistantships. Only 5000-level or higher courses, and no more than the number of credits specified by the program catalog, may be applied toward both degrees. In addition to the admission requirements of the combined BS/MS program, students must meet all the admission requirements of the University Graduate School.

Students enrolled in the program may count up to six credit hours of MME graduate courses as credits for both the BS and MS degrees. The combined BS/MS program has been designed to be a continuous program. During this combined BS/MS program, upon completion of all the requirements of the undergraduate program, students will receive their BS degrees. Students in this program have

up to three major semesters to complete the master's degree after receipt of the bachelor's degree. Students who fail to meet this three-major-semester post BS requirement or who elect to leave the combined program at any time and earn only the BS degree will have the same access requirements to regular graduate programs as any other student, but will not be able to use the six credits in both the bachelor's and master's degrees.

For each of the graduate courses counted as credits for both BS and MS degree, a minimum grade of "B" is required. Students enrolled in the program may count up to six credit hours of MME graduate courses toward the elective engineering BS requirements as well as toward the MS degree. Only graduate courses with formal lectures can be counted for both degrees. The students are responsible for confirming the eligibility of each course with the undergraduate advisor.

Students interested in the program should consult with the undergraduate advisor on their eligibility to the program. The students should also meet the graduate advisor to learn about the graduate program and available courses before completing the application form and submitting it to the undergraduate advisor. Applicants will be notified by the department and the University Graduate School of the decision on their applications.

Master of Science in Materials Science and Engineering

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. If a student is requesting financial assistance, Graduate Record Examination (GRE) with the following minimum scores on the individual components: verbal ≥143 and quantitative ≥151 is also required.
3. Applicants who have not satisfied the above will be evaluated for conditional 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 80 on the iBT TOEFL (equivalent to 550 on the paper-based version, or 213 on the computer-based version of the Test of English as a Foreign Language) or 6.5 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 three department core course requirements plus the elective courses in the student's major area.
4. Completed undergraduate course deficiencies specified at admission, if any, with no grades below 'C' and a GPA ≥ 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 ≥ 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.
6. Non-thesis option: Successfully completed a minimum of 27 semester hours of graduate course work as specified in an approved study plan containing at least 9 hours of 6000 level courses and a 3 credit hour project with a GPA ≥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).
7. Thesis degree: Successful public oral defense of the thesis. Submission of the approved thesis to the Graduate School.
8. Non-thesis degree: Successful completion of a formal report and presentation.
9. Students must achieve an overall GPA ≥ 3.0 in all graduate work completed at FIU in their approved study plan.
10. Completed one semester of the Graduate Seminar course.
11. 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 MME Graduate

Seminar.

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 University Graduate School consisting of a least three graduate 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 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 exam the student will implement the committee's suggestions for improving the draft document. Each committee member must sign the approval form in the final document. Hardcover bound copies of the approved thesis must be provided to the advisor and the department. Students should become familiar with the University Graduate School's regulations and deadlines available on line at **http://gradschool.fiu.edu**.

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
Ceramics
Polymers and Biomaterials
Nanomaterials

Course Requirements

All MSMSE degree seeking students must take the following three 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
EMA 5507C	Analytical Methods in Material Science	3
EML 6935	Graduate Seminar	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 5140	Introduction to Ceramic Materials	3
EMA 5295	Principles of Composite Materials	3
EMA 5200	Nanomechanics and Nanotribology	3
EGM 5354	Finite Element Method Applications in Mechanical Engineering	3
EGN 5367	Industrial Materials and Engineering Design	3
EMA 6126	Adv. Physical Metallurgy	3
EMA 6127C	Advanced Physical and Mechanical Metallurgy	3
EML 6233	Fatigue and Failure Analysis	3
EGM 6355	Nonlinear Finite Element Analysis	3
EML 5509	Optimization Algorithms	3
EML 5562	Adv. Electronic Packaging	3
EML 6908	Independent Study	1-3
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
EMA 6165	Polymer Physics and Analytical Techniques	3
EEE 6399C	Electronic Properties of Material Science	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:

1. GPA of at least 3.0/4.0 in the last 60 upper level credit hours
2. GRE of at least 151 on the quantitative component.
3. Three letters of recommendation.

4. 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 80 on the iBT TOEFL (equivalent to 550 on the paper-based version, or 213 on the computer-based version of the Test of English as a Foreign Language) or 6.5 overall on the IELTS is required.
5. 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 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 Ph.D. 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 75 credit hours, of which at least 45 hours must be coursework and 15 hours dissertation. The credit hours earned towards the Ph.D. program have the following requirements:

1. At least 21 credits at the 5000 level or higher, not to include dissertation.
2. At least 12 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 the student's own field.
4. Two applied/computational mathematics courses as suggested for M.S. program.
5. A minimum of 15 credits of dissertation.
6. 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.
7. EML 6908 Independent Studies counts for a maximum of 6 credit hours of coursework.
8. EML 6910 Supervised Research counts for a maximum of 6 credit hours of coursework.
9. EML 6935 Graduate Seminar (zero credits) should be registered every semester until the advancement to candidacy (D-2).

Applicants entering the Ph.D. program with a Masters degree in Mechanical Engineering are required to complete at least 45 credit hours, of which at least 24 hours must be coursework and 15 hours dissertation. The credit hours earned towards the Ph.D. program have the following requirements:

1. Breadth criteria could be satisfied by taking 3 courses in a field/area outside the student's own field.
2. A minimum of 12 credits of 6000 higher, not to include dissertation.
3. A minimum of 15 credits of dissertation.
4. Additional courses to be determined by candidate's dissertation committee.
5. EML 6908 Independent Studies counts for a maximum of 6 credit hours of coursework.
6. EML 6910 Supervised Research counts for a maximum of 6 credit hours of coursework.
7. EML 6935 Graduate Seminar (zero credits) should be registered every semester until the advancement to candidacy (D-2).

Applicants having a Master's Degree in any other Engineering discipline from an accredited institution may transfer a maximum of 24 semester hours as part of their requirements.

Elective Courses: Possible elective courses from the Mechanical Engineering department include:

Thermo/Fluid

EAS 6721	Advanced Aerodynamic Shape Design
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

EAS 5221	Design and Analysis of Aerospace Structures
EGM 5346	Computational Engineering Analysis
EGM 5354	Finite Element Method Applications in Mechanical Engineering
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 Techniques of Materials Science
EMA 5200	Nanomechanics and Nanotribology
EMA 6127C	Advanced Physical & Mechanical Metallurgy
EMA 6165C	Polymer Physics & Analytical Techniques
EML 5505	Smart Machine Design and Development
EML 5509	Optimization Algorithms
EML 5125	Classical Dynamics
EML 5385	Identification Techniques of Mechanical Systems
EML 5562	Advanced Electronic Packaging
EML 6223	Advanced Mechanical Vibration

	Analysis
EML 6233	Fatigue and Failure Analysis
EML 6805	Advanced Design of Robot

Design and Manufacturing

EAS 5221	Design and Analysis of Aerospace Structures
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	Optimization Algorithms
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 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.

Stages of Progression Towards Degree

A student must demonstrate acquisition of graduate knowledge in five incremental stages in order to be awarded a Ph.D. in Mechanical Engineering:

I. Formation of the Dissertation Committee

Students must select a dissertation advisor during their first semester of study. Students must select a dissertation committee and submit the D-1 form at least one semester before their first attempt to take the Comprehensive Examination.

II. Comprehensive Exam (CE)

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

III. Admission to Candidacy

Candidacy status indicates that a doctoral student is ready to commence working on the dissertation. A student is admitted to candidacy upon successfully completing all required course work and passing the Comprehensive Examination. After completion of coursework credits and the Comprehensive Exam, form D-2 must be turned in.

IV. 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 within 6 months after taking and passing the Comprehensive Exam. After completion of proposal defense, form D-3 must be turned in.

V. Final Defense (FD)

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

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 Manual"). 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, in addition to the copies required by the University Graduate School.

Financial Aid

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

Doctor of Philosophy in Materials Science and Engineering

The Ph.D. in Materials Science and Engineering will prepare graduates for industrial and/or academic research as well as for higher level jobs in materials related industry in one (or more) of five areas of specialization: 1) electronic materials, 2) nanotechnology, 3) metals and alloys, 4) ceramics, and 5) polymer science and biomaterials.

Admission Requirements

The requirements for admission to the doctoral program in Materials Science and Engineering for applicants having a Bachelor's degree in Materials Science and Engineering or in a related field, e.g. Mechanical Engineering, Electrical Engineering, Physics, Chemistry, and Geophysics from an accredited institution are the following:

1. GPA of at least 3.0/4.0 in the last 60 credit hours attempted.
2. GRE of at least 151 on the quantitative component.
3. Three letters of recommendation.
4. 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 80 on the iBT TOEFL (equivalent to 550 on the paper-based version, or 213 on the computer-based version of the Test of English as a Foreign Language) or 6.5 overall on the IELTS is required.
5. Applicants having a Master's degree in Materials Science and 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.

Course Requirements

Applicants having a Bachelor's Degree are required to complete at least 75 credit hours, out of which at least 45 hours must be coursework and 15 hours dissertation. The credit hours earned towards the Ph.D. program have the following requirements:

- At least 21 credits at the 5000 level or higher, not to include dissertation.
- At least 12 credits at the 6000 level or higher, not to include dissertation.
- EML 6908 Independent Studies counts for a maximum of 6 credit hours of coursework.
- EML 6910 Supervised Research counts for a maximum of 6 credit hours of coursework.
- EML 6935 Graduate Seminar (zero credits) should be registered every semester until the advancement to candidacy (D-2).

Applicants having a Master's Degree in Materials Science, Materials Engineering, and Metallurgical Engineering are required to complete at least 45 credit hours, out of which at least 24 hours must be coursework and 15 hours dissertation. The credit hours earned towards the Ph.D. program have the following requirements:

- At least 12 credits at the 6000 level or higher, not to include dissertation.
- EML 6908 Independent Studies counts for a maximum of 6 credit hours of coursework.
- EML 6910 Supervised Research counts for a maximum of 6 credit hours of coursework.
- EML 6935 Graduate Seminar (zero credits) should be registered every semester until the advancement to candidacy (D-2).

Applicants having a Master's Degree in any other Engineering discipline from an accredited institution may transfer a maximum of 24 semester hours from their previous course of study.

Materials Science and Engineering Courses

Fundamentals

EMA 5001	Physical Properties of Materials (Required core course for MSMSE)
EMA 5106	Thermodynamics and Kinetics of Materials (Required core course for MSMSE)
EMA 5507C	Analytical Techniques of Materials Science (Required core course for MSMSE)

These 3 or equivalent courses should be taken by all PhD students in Materials Engineering

Specialty Areas

Metals and Alloys

EMA 5104	Advanced Mechanical Properties of Materials
EMA 5295	Principle of Composite Materials
EMA 6126	Advanced Physical Metallurgy
EMA 6127C	Advanced Physical and Mechanical Metallurgy
EMA 6185	Advanced Mechanics of Composites
EGM 6570	Fracture Mechanics
EGM 7574	Advanced Fracture Mechanics
EML 6233	Fatigue and Fracture Analysis

Electronic Materials

EEL 6315	Advanced Solid State Electronics
EEL 6399	Electronic Properties of Materials
EMA 5016	Nanoelectronic Materials
PHZ 6426	Advance Solid State Physics
PHZ 5405	Solid State Physics

Ceramics

EMA 5140	Introduction to Ceramic Materials
EMA 6646	Ceramic Processing
EMA 6449	Electronic Properties of Ceramic Materials

Polymers

CHM 6511	Polymer Chemistry
EMA 5584	Biomaterials Science
EMA 6165C	Polymer Physics and Analytical Techniques
EMA 6264	Mechanical Properties of Polymers
EMA 6665	Polymer Processing and Engineering

Analytical Techniques in Materials Science

EMA 6516	Crystallography and X-ray Diffraction
EMA 6518	Transmission Electron Microscopy
GLY 5287C	Scanning Electron Microscopy with EDS Analysis
GLY 5288C	Electron Microprobe Microanalysis with EDS Analysis
PHZ 6437	Surface Physics

Nano Structured Materials

EEL 6315	Advanced Solid State Electronics
EEL 6332	Thin Film Engineering

EMA 5017	Nanoparticle Technology
EMA 5015	Introduction to Nanomaterials
EMA 5016	Nanoelectronic Materials

It is important that there will be three 6000 level courses developed for each specialization.

Stages of Progression Towards Degree

A student must demonstrate acquisition of graduate knowledge in five incremental stages in order to be awarded a Ph.D. in Materials Science Engineering:

I. Formation of the Dissertation Committee

Students must select a dissertation advisor during their first semester of study. Students must select a dissertation committee and submit the D-1 form at least one semester before their first attempt to take the Comprehensive Examination.

II. Comprehensive Exam (CE)

The Comprehensive Examination is the general written and oral exam to test master's level knowledge. A student who is admitted to the Ph.D. program with a bachelor's degree must take the CE no later than the second term of the 2nd year after admission, and a student who enters the Ph.D. program with a master's degree must take and pass the CE no later than the 2nd term after admission. Students may petition for exceptions from the graduate student committee. A student who fails the CE may retake the CE exam only once.

III. Admission to Candidacy

Candidacy status indicates that a doctoral student is ready to commence working on the dissertation. A student is admitted to candidacy upon successfully completing all required course work and passing the Comprehensive Examination. After completion of coursework credits and the Comprehensive Exam, form D-2 must be turned in.

IV. 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 within 6 months after taking the Comprehensive Examination. After completion of proposal defense, form D-3 must be turned in.

V. Final Defense (FD)

There will be a public defense at a graduate seminar. The defense can be failed no more than once. 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 of graduate degrees must confirm to University guidelines (see "Regulations for Thesis and Dissertation Preparation Manual"). One final and approved copy of the dissertation must be delivered to the Chairperson of the Department of Mechanical and Materials Engineering in addition to the copies required by the University Graduate School.

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 5221 Design and Analysis of Aerospace Structures (3). Fundamental principles of aircraft design and analysis. Advanced computational methods used for analysis of aerospace structures. Prerequisites: EML 3032, MAP 2302 or EGM 3311, EMA 3702, EML 4140.

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.

EAS 6212 Aeroelasticity (3). Understanding and analysis of aeroelastic phenomena in fixed-wing aircraft, aero-structural dynamics, static aeroelasticity, dynamic aeroelasticity, and dynamic response and transient stresses. Prerequisite: Permission of the instructor.

EAS 6721 Advanced Aerodynamic Shape Design (3). Analytical formulations and numerical algorithms for inverse shape design and optimized shape design of 2D and 3D aerodynamic and aerothermal configurations over a range of flow regimes. Prerequisites: Permission of the instructor. Good programming skills. Basic courses in fluid mechanics.

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 2032, MAP 2302, 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 2032, EMA 3702, and EML 4140.

EGM 5371 Meshfree and Alternative Methods in Mechanical Engineering (3). Course covers the alternative methods in engineering analysis with a special focus on meshfree method with distance fields in mechanical engineering. Prerequisites: EML 3036, (MAP 2302 or EGM 3311), EGM 5354, or permission of the instructor.

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 the 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). Modeling of vibrational and dynamic systems including solution of governing equations by analytical and numerical techniques. Prerequisites: EGM 5346 or permission of the instructor.

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.

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 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 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 5013C Nanoscale Fabrication and Synthesis (3). This course covers the advanced micro/nanofabrication tools and techniques. It includes lab sessions where the students design, fabricate and test selected micro/nano-scale devices.

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: EGN 3365.

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 5200 Nanomechanics and Nanotribology (3). Mechanical and tribological properties at nano-scale length, fundamentals of nanoindentation and nanoDMA, application of nanoindentation for hard, soft, natural and biological materials. Prerequisites: EGN 3365 or permission of the instructor.

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 5305 Electrochemical Engineering (3). Introduction to graduate students the fundamental principles of electrochemistry and its applications in different engineering systems for energy, chemical, biomedical, and electronics industries. Prerequisite: Permission of the instructor.

EMA 5326 Corrosion Science and Engineering (3). Electrochemical principles of corrosion, methods of

corrosion control and measurement. Prerequisites: EGN 3365 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 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 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 6113 Advanced Materials Thermodynamics (3). Advanced thermodynamic study of materials using thermochemical and computational methods. Prerequisite: EMA 5106.

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 4804.

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, electro-magnetic, 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, polhade and herpolhade, theory of tops and gyroscopes. Variational principles. Hamiltonian equations of motion. Poinsote 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 4804.

EML 5290 Fundamentals of Microfabrication (3). Science of miniaturization will be introduced. Materials choices, scaling laws, different options to make very small machines and practical applications will be emphasized.

Progress related to state-of-the-art BioMicroElectro Mechanical Systems will be presented.

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 4804 or permission of the instructor.

EML 5509 Optimization Algorithms (3). Multi-disciplinary numerical analysis combined with single objective and multi-objective unconstrained and constrained optimization and sensitivity analysis techniques to optimize the design. Prerequisites: 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 planer kinematic systems will be emphasized. Prerequisites: EML 4535 or permission of the instructor.

EML 5555 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 6357C, and MAN 6209.

EML 5559 Design, Production and Marketing (3). Student teams will evaluate the market and identify promising mechatronics systems. They will simulate design, development, and commercialization of the products in realistic environment.

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 2032 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 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 4804, 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 4804, EML 4503, or equivalent, or permission of the instructor.

EML 5927 Professional Development and Leadership for Mechanical Engineers (3). Consequences of engineering and concepts for personal career management, decision making leadership, and entrepreneuring that enhance the effectiveness of professional engineering practice. Prerequisite: Senior standing in engineering.

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 6153 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). Multi degree-of-freedom systems, discrete and continuous systems; vibration control and introduction to vibration of non-linear systems. Prerequisites: EML 3222 or 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: Consent of the instructor.

EML 6712 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. Prerequisite: Consent of the instructor.

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 4806, 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 (1-3). Graduate students gain work experience through supervised internship in industry. The student prepares an 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). Master's 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 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 advances in existing and emerging areas of research. Prerequisite: Ph.D. students only.

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