Mechanical Engineering (MEEN)

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

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

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

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

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

Manufacturing and Materials Systems
A concentration in manufacturing and materials systems engineering allows students to focus on a broad range of topics. These topics range from micro issues, such as material-related issues and cutting mechanisms in material removal processes, to macro analysis of complex manufacturing systems from either a process or ergonomics perspective. The focus of this concentration may be computer integrated manufacturing, material processing, mechanical behavior of materials, manufacturing processes, quality systems or ergonomics within manufacturing. Normally, each of these multi-disciplinary areas requires certain core courses along with specialized studies, which may include advanced courses in other engineering disciplines, courses in mathematics and statistics and/or courses in business administration. Current research topics include: cellular manufacturing, polishing and mass finishing processes, rapid prototyping, robotic systems, production integration (JIT, TQC, CIM), ergonomics of assembly operations, reliability/quality estimation, human performance and safety evaluation and materials forming and joining processes.

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

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

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

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

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

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

Upon enrolling in the master of science in mechanical engineering program, a student selects one of three areas of specialization: energy systems, manufacturing and materials systems, or mechanical systems. Upon selection of a faculty adviser, a curriculum is designed along with a research program to address the specific goals of the student. Programs will include course work in engineering, mathematics and science with the following requirements:

- A minimum of 24 credit hours of course work.
- A minimum of 3 credit hours of an approved math course (MEEN 6101, MEEN 6102, or MEEN 6103).
- A minimum of one half of the total course work must be at the 6000 level.
- A minimum of one half of the total course work must be taken from the Department of Mechanical Engineering.
- At most, a maximum of 3 credit hours of an Independent Study course may be included in the course work total.
- Six (6) credit hours of thesis work, completion of a comprehensive exam and submission of an approved thesis.
- The student must attend and participate in the departmental graduate seminar series (MEEN 6960).

A maximum of 6 credit hours of graduate-level credit from other approved institutions may be accepted toward the requirement of the degree.

**Master’s Learning Outcomes**

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

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

The accelerated program enables students to earn both a master of science degree and a bachelor of science degree from the College of Engineering in the span of five years. Only the thesis option is available with this program. Qualified students (3.50/4.0 GPA) who are enrolled in the Department of Mechanical Engineering at Marquette University may apply for admission to this program during their undergraduate junior year. Students must submit an application to the Graduate School, indicate their interest in the five year program, and meet all other admission criteria as stated in the Application Requirements section.

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

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

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

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

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

- 30 credit hours of course work.
- A minimum of 3 credit hours of an approved math course (MEEN 6101, MEEN 6102 or MEEN 6103).
- A minimum of one half of the total course work must be at the 6000 level.
- A minimum of one half of the total course work must be taken from the Department of Mechanical Engineering.
- At most, a maximum of 3 credit hours of an Independent Study course may be included in the course work total.
- Completion of a capstone comprehensive examination consisting of two parts:
  1. A mathematics portion drawn from material presented in MEEN 6101 Advanced Engineering Analysis 1.
  2. An area of specialization portion drawn from material presented from the area of specialization selected:
     Energy Systems: MEEN 5350 Transport Phenomena and MEEN 5360 Intermediate Thermodynamics
• A maximum of 6 credit hours of graduate-level credit from other approved institutions may be accepted toward the requirement of the degree.

Master’s Learning Outcomes

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

Mechanical Engineering Doctoral Requirements

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

A doctoral student must complete a program of study prepared in collaboration with their permanent adviser and outlined on an approved Doctoral Program Planning Form. This form must be submitted within the first year of the student’s doctoral studies. The program normally requires 48 credit hours of course work beyond the baccalaureate degree, plus 12 credit hours of dissertation work. In cases in which the student enters the program with a master’s degree in mechanical engineering or a closely related field, the student may request that the department and the Graduate School allow credits from the master’s degree to satisfy up to 24 credit hours of the required course work. At least one-half of the total course work requirement must be from designated graduate-level courses. Students are required to take at least one-half of their total course work from the Department of Mechanical Engineering course offerings. A maximum of 6 credit hours of graduate-level credit from other accredited institutions may be accepted toward the requirements of the degree. Independent study course work can account for a maximum of 3 credit hours. All doctoral students are required to participate in the department graduate seminar activities and complete all university Graduate School requirements.

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

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

Doctoral Learning Outcomes

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

Courses

**MEEN 5220. Intermediate Dynamics. 3 cr. hrs.**

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

**MEEN 5230. Intermediate Mechanics of Materials. 3 cr. hrs.**

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

**MEEN 5240. Polymers and Polymer Composites. 3 cr. hrs.**

Introduction to physical/chemical structure of polymers, polymer characterization, polymer material properties and mechanical testing methods, elastic and viscoelastic polymer response, processing methods, composite materials, and the selection of polymers in design applications.

**MEEN 5245. Fatigue and Fracture Mechanics. 3 cr. hrs.**

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

**MEEN 5250. Design of Machine Elements 2. 3 cr. hrs.**

Detailed design of gears and cams. Emphasizes integration of dynamics into design of machinery. Topics include balancing of machinery, selection of motors and critical frequency analysis, and miscellaneous power transmission components. Use of spreadsheets and computer programs to assist in the design of various components.
MEEN 5265. Intermediate Finite Element Method. 3 cr. hrs.
Introduces the finite element solution method for linear, static problems. Includes calculation of element stiffness matrices, assembly of global stiffness matrices, exposure to various finite element solution methods, and numerical integration. Emphasizes structural mechanics, and also discusses heat transfer and fluid mechanics applications in finite element analysis. Computer assignments include development of finite element code (FORTRAN or C) and also use of commercial finite element software (ANSYS and/or MARC). Prereq: MEEN 3260 or equiv.

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

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

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

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

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

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

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

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

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

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

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

MEEN 5460. Work Measurement and Facilities Design. 3 cr. hrs.
Concentrates on how to quantify work and how to design work tasks, based on measurement and methods engineering, to achieve optimal performance. Involves analysis and evaluation of facilities for industrial and service operations and designing facilities, regardless of size, for various types of operations.

MEEN 5475. Ergonomics. 3 cr. hrs.
Covers biomechanical and physiologic aspects of workplace design, such as engineering anthropometry, cumulative trauma disorders, (including carpal tunnel syndrome), low back injuries, hand tool design and evaluation, methods of surveillance in industrial environments, modeling, and ergonomics guidelines. Laboratory sessions are offered to demonstrate ergonomic principles and also provide students with hands-on experience in collecting data and conducting experiments. Two hrs. lec., 2 hrs. lab.
MEEN 5485. Welding Engineering. 3 cr. hrs.
Arc welding physics, fundamentals of power supplies and welding circuits, fusion and solid-state welding processes, weld testing, analysis of welded joints, demonstrations using various processes.

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

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

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

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

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

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

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

MEEN 6310. Advanced Fluid Mechanics. 3 cr. hrs.
Further development of fluid flow theory starting with classic potential flow solutions. Numerical and analytical techniques for both inviscid and viscous fluid flows, including boundary layer theory and stability. Transition routes and chaos with an introduction to turbulence. Prereq: MEEN 5350 or equiv.; computer programming experience recommended.

MEEN 6330. Statistical Thermodynamics. 3 cr. hrs.

MEEN 6340. Thermal Radiation Heat Transfer. 3 cr. hrs.
MEEN 6350. Convective Heat and Mass Transfer. 3 cr. hrs.
Principles and mechanisms of convective transports of energy and of chemical species associated with laminar and turbulent flows, including condensation and boiling. Calculation of heat and mass transport coefficients. Mathematical modeling, with applications to engineering devices involving several of these processes, with and without phenomenological coupling. Prereq: MEEN 6310.

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

MEEN 6370. Combustion Chemistry and Mechanisms. 3 cr. hrs.
Advanced theoretical, experimental and numerical techniques for studying the chemistry and kinetic mechanisms of combustion. The technical content for includes gas phase chemical kinetics, a discussion of experimental and theoretical techniques for evaluating kinetic rate coefficients, and strategies for the development and reduction of kinetic mechanisms intended for modeling combustion reactions. Topics relevant to statistical thermodynamics and the physical dynamics of technical flames may be covered. Prereq: MEEN 3340 or equiv.

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

MEEN 6473. Computer Integrated Manufacturing. 3 cr. hrs.
Primary objectives include the validation of the underlying philosophy behind computer integrated manufacturing and the definition of characteristics of various components which constitute a C.I.M. environment. Describes the benefits of C.I.M. and how to upgrade conventional plants to a C.I.M. operation.

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

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

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

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

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

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

MEEN 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

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

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

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

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

MEEN 9983. Graduate Research: Full Time. 0 cr. hrs.
Zero credit, full-time equivalency course for Graduate Research.

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

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

MEEN 9986. Master's Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.
MEEN 9987. Doctoral Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

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

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

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

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

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

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

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

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