# MECHANICAL ENGINEERING

For the undergraduate curriculum in mechanical engineering leading to the degree bachelor of science. The Mechanical Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org/.

Mechanical engineers apply the principles of motion, energy, and force to create mechanical solutions to technological problems, thereby realizing devices and systems that make life better. About one-fifth of all engineers practicing today are mechanical engineers. Their skills are used in research, development, design, testing, production, technical sales, technical management, as well as medicine, law, and business. Mechanical engineers are characterized by personal creativity, breadth of knowledge, and versatility. For these reasons they are found to function and thrive as valuable members and leaders of multidisciplinary teams. Mechanical engineers are employed in a wide range of industries; examples include agricultural/heavy equipment, biomedical, consulting, energy and power, manufacturing, product design and transportation.

The mechanical engineering curriculum at Iowa State University is dedicated to preparing students for productive careers in the state, nation, and the world and has the following objectives:

1. Graduates will have utilized a foundation in engineering and science to improve lives and livelihoods through a successful career in mechanical engineering or other fields.
2. Graduates will have become effective collaborators and innovators, leading or participating in efforts to address social, technical and business challenges.
3. Graduates will have engaged in life-long learning and professional development through self-study, continuing education or graduate and professional studies in engineering, business, law or medicine.

The mechanical engineering curriculum is organized to provide students with a broad foundation in mathematics, science, engineering, social science and humanities. The mechanical engineering disciplinary areas emphasized are design and optimization, dynamic systems and control, materials processing and mechanics, and thermo-fluid sciences. Elective courses provide additional emphasis in terms of the student's unique educational goals, whether they include immediate entry into industry or further professional or graduate study.

A major focus throughout the mechanical engineering curriculum is a series of experiences that emphasize engineering design, culminating in a capstone design experience in the senior year. Students will develop engineering judgment through open-ended problems that require establishment of reasonable engineering assumptions and realistic constraints. Development of skills needed to be independent, creative thinkers, effective communicators, and contributing team members is emphasized throughout the curriculum. Students also develop an understanding of the societal context in which they will practice engineering, including environmental, legal, aesthetic, and human aspects.

Students are encouraged to participate in the cooperative education program or to obtain engineering internships, both domestically and abroad. Study abroad is encouraged, and the department has exchange programs with several universities around the world. These experiences help students to round out their education and to better prepare for careers in the increasingly global practice of engineering.

## Curriculum in Mechanical Engineering

Administered by the Department of Mechanical Engineering. Leading to the degree bachelor of science.

**Total credits required: 129 cr.**
**Any transfer credit courses applied to the degree program require a grade of C or better (but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA). See also Basic Program and Special Programs.**
**International Perspectives: 3 cr.** [1]
**U.S. Diversity: 3 cr.** [1]
**Communication Proficiency/Library requirement:**

| | | |
|---|---|---|
| ENGL 150 | Critical Thinking and Communication (Must have a C or better in this course) | 3 |
| ENGL 250 | Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course) | 3 |
| LIB 160 | Information Literacy | 1 |
| Choose one of the following communication courses (minimum grade of C) | | 3 |
| ENGL 302 | Business Communication | |
| ENGL 309 | Proposal and Report Writing | |
| ENGL 314 | Technical Communication | |
| SP CM 212 | Fundamentals of Public Speaking | |

**General Education Electives: 15 cr.**
No more than three 100-level courses for this set of courses can be applied to the Bachelor of Science Degree in Mechanical Engineering.

| | | |
|---|---|---|
| Choose one course from the following: | | 3 |
| ECON 101 | Principles of Microeconomics | |
| or ECON 102 | Principles of Macroeconomics | |
| Social Science [2] | | 3 |
| Humanities | | 6 |
| Humanities or Social Science [2] | | 3 |
| **Total Credits** | | **15** |

**Basic Program: 24 cr.**
A minimum GPA of 2.00 is required for this set of courses (please note that transfer course grades will not be calculated into the Basic Program

GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

| | | |
|---|---|---|
| CHEM 167 | General Chemistry for Engineering Students | 4 |
| or CHEM 177 | General Chemistry I | |
| ENGL 150 | Critical Thinking and Communication (Must have a C or better in this course) | 3 |
| ENGR 101 | Engineering Orientation | R |
| M E 160 | Mechanical Engineering Problem Solving with Computer Applications [3] | 3 |
| LIB 160 | Information Literacy | 1 |
| MATH 165 | Calculus I | 4 |
| MATH 166 | Calculus II | 4 |
| PHYS 221 | Introduction to Classical Physics I | 5 |
| **Total Credits** | | **24** |

**Mechanical Engineering Foundations: 25 cr.**

A minimum GPA of 2.00 for the complete group of Foundations courses is required before students are permitted to enroll in the following Mechanical Engineering Core courses (please note that transfer course grades will not be calculated into the ME Foundations GPA): ME 324, ME 325, ME 332, ME 335, ME 370 and ME 421.

| | | |
|---|---|---|
| MATH 265 | Calculus III | 4 |
| 4 credits from the following: | | 4 |
| MATH 267 | Elementary Differential Equations and Laplace Transforms | |
| MATH 266 & MATH 268 | Elementary Differential Equations and Laplace Transforms | |
| PHYS 232 | Introduction to Classical Physics II | 4 |
| PHYS 232L | Introduction to Classical Physics II Laboratory | 1 |
| E M 324 | Mechanics of Materials | 3 |
| MAT E 273 | Principles of Materials Science and Engineering | 3 |
| M E 231 | Engineering Thermodynamics I | 3 |
| C E 274 | Engineering Statics | 3 |
| **Total Credits** | | **25** |

**Mechanical Engineering Core: 38 cr.**

A minimum GPA of 2.00 is required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Core GPA):

| | | |
|---|---|---|
| M E 345 | Engineering Dynamics | 3 |
| E E 442 | Introduction to Circuits and Instruments | 2 |
| E E 448 | Introduction to AC Circuits and Motors | 2 |
| M E 270 | Introduction to Mechanical Engineering Design | 3 |
| M E 324 | Manufacturing Engineering | 3 |
| M E 324L | Manufacturing Engineering Laboratory | 1 |
| M E 325 | Mechanical Component Design | 3 |
| M E 332 | Engineering Thermodynamics II | 3 |
| M E 335 | Fluid Flow | 4 |
| M E 370 | Engineering Measurements | 3 |
| M E 421 | System Dynamics and Control | 4 |
| M E 436 | Heat Transfer | 4 |
| One Senior Capstone Design course from the following | | 3 |
| M E 415 | Mechanical Systems Design | |
| M E 442 | Heating and Air Conditioning Design | |
| M E 466 | Multidisciplinary Engineering Design | |
| **Total Credits** | | **38** |

**Other Remaining Courses: 27 cr.**

| | | |
|---|---|---|
| Complete 15 cr. Technical Electives [2] | | 15 |
| M E 170 | Engineering Graphics and Introductory Design | 3 |
| M E 202 | Mechanical Engineering - Professional Planning | R |
| ENGL 250 | Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course) | 3 |
| STAT 305 | Engineering Statistics | 3 |
| Complete one of the following communication courses with a minimum grade of C. | | 3 |
| ENGL 302 | Business Communication | |
| ENGL 309 | Proposal and Report Writing | |
| ENGL 314 | Technical Communication | |
| SP CM 212 | Fundamentals of Public Speaking | |
| **Total Credits** | | **27** |

**Co-op/Internships (Optional)**

1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also approved by the department to meet other course requirements within the degree program.
   U.S. diversity and international perspectives courses may not be taken Pass/Not Pass.
2. Choose from department approved list of technical electives (http://www.me.iastate.edu/students/degrees-and-programs/bs-degree/degree-requirements/tech-electives/) and general education electives (http://www.me.iastate.edu/students/degrees-and-programs/bs-degree/degree-requirements/general-education/). Note: electives used to meet graduation requirements may not be taken Pass-Not Pass (P-NP).
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.

### Transfer Credit Requirements

The Mechanical Engineering Department requires a grade of a C or better for any transfer credit course that is applied to the degree program. The degree program must include a minimum of 15 credits taken from courses offered through the Mechanical Engineering Department at Iowa State University. Of these 15 credits, 3 must be from one of the senior capstone design courses. The remaining 12 credits may be from the core curriculum program (if a student is deficient in these courses) or from 400-level M E technical electives. No more than 3 credits of independent study shall be applied to meet the 12 credit requirement.

See also: A 4-year plan of study grid showing course template by semester. (http://catalog.iastate.edu/previouscatalogs/2021-2022/collegeofengineering/mechanicalengineering/#fouryearplantext)

## Energy Systems Minor

The Energy Systems minor is administered by the mechanical engineering department and is open to all undergraduates in the College of Engineering. The minor may be earned by completing 15 credits from the following courses. The complete list of approved elective courses can be found below. The minor must include at least 9 credits that are not used to meet any other department, college, or university requirement.

http://www.me.iastate.edu/energy-systems-minor/

Required courses

| | | |
|---|---|---|
| ECON 380 | Energy, Environmental and Resource Economics | 3 |
| E E 351 | Analysis of Energy Systems | 3 |
| or M E 433 | Alternative Energy | |
| Electives: Choose from a list of approved courses | | 9 |
| **Total Credits** | | **15** |

Approved Elective Courses

| | | |
|---|---|---|
| A B E 325 | Biorenewable Systems | 3 |
| A B E 342 | Agricultural Tractor Power | 3 |
| A B E 363 | Agri-Industrial Applications of Electric Power and Electronics | 4 |
| A B E 380 | Principles of Biological Systems Engineering | 3 |
| A B E 413 | Fluid Power Engineering | 3 |
| A B E 472 | Design of Environmental Modification Systems for Animal Housing | 3 |
| A B E 480 | Engineering Analysis of Biological Systems | 3 |
| A B E 572 | Design of Environmental Modification Systems for Animal Housing | 3 |
| A B E 580 | Engineering Analysis of Biological Systems | 3 |
| AER E 381 | Introduction to Wind Energy | 3 |
| AER E 481 | Advanced Wind Energy: Technology and Design | 3 |
| AER E 570 | Wind Engineering | 3 |
| CH E 356 | Transport Phenomena I | 3 |
| CH E 357 | Transport Phenomena II | 3 |
| CH E 358 | Separations | 3 |
| CH E 381 | Chemical Engineering Thermodynamics | 3 |
| CH E 382 | Chemical Reaction Engineering | 3 |
| CH E 415 | Biochemical Engineering | 3 |
| CH E 515 | Biochemical Engineering | 3 |
| CH E 554 | Integrated Transport Phenomena | 4 |
| CH E 583 | Advanced Thermodynamics | 3 |
| CH E 587 | Advanced Chemical Reactor Design | 3 |
| CON E 352 | Mechanical Systems in Buildings | 3 |
| CON E 353 | Electrical Systems in Buildings | 3 |
| CON E 354 | Building Energy Performance | 3 |
| E E 303 | Energy Systems and Power Electronics | 3 |
| E E 448 | Introduction to AC Circuits and Motors | 2 |
| E E 452 | Electrical Machines and Power Electronic Drives | 3 |
| E E 455 | Introduction to Energy Distribution Systems | 3 |
| E E 456 | Power System Analysis I | 3 |
| E E 457 | Power System Analysis II | 3 |
| E E 458 | Economic Systems for Electric Power Planning | 3 |
| E E 459 | Electromechanical Wind Energy Conversion and Grid Integration | 3 |
| E E 552 | Energy System Planning | 3 |
| E E 553 | Steady State Analysis | 3 |
| E E 554 | Power System Dynamics | 3 |
| E E 555 | Advanced Energy Distribution Systems | 3 |
| E E 556 | Power Electronic Systems | 3 |
| E E 559 | Electromechanical Wind Energy Conversion and Grid Integration | 3 |
| E M 570 | Wind Engineering | 3 |
| ENGR 340 | Introduction to Wind Energy: System Design & Delivery | 3 |
| ENSCI 480 | Engineering Analysis of Biological Systems | 3 |
| I E 543 | Wind Energy Manufacturing | 3 |
| M E 332 | Engineering Thermodynamics II | 3 |
| M E 335 | Fluid Flow | 4 |
| M E 413 | Fluid Power Engineering | 3 |
| M E 436 | Heat Transfer | 4 |
| M E 437 | Introduction to Combustion Engineering | 3 |
| M E 441 | Fundamentals of Heating, Ventilating, and Air Conditioning | 3 |
| M E 442 | Heating and Air Conditioning Design | 3 |
| M E 444 | Elements and Performance of Power Plants | 3 |

| | | |
|---|---|---|
| M E 448 | Fluid Dynamics of Turbomachinery | 3 |
| M E 449 | Internal Combustion Engines | 3 |
| M E 501 | Fundamentals of Biorenewable Resources | 3 |
| M E 530 | Advanced Thermodynamics | 3 |
| M E 532 | Compressible Fluid Flow | 3 |
| M E 535 | Thermochemical Processing of Biomass | 3 |
| M E 536 | Advanced Heat Transfer | 3 |
| M E 538 | Advanced Fluid Flow | 3 |
| M E 542 | Advanced Combustion | 3 |
| M E 545 | Thermal Systems Design | 3 |
| M S E 520 | Thermodynamics and Kinetics in Multicomponent Materials | 3 |
| MAT E 311 | Thermodynamics in Materials Engineering | 3 |
| POL S 515 | Biorenewables Law and Policy | 3 |

Mechanical Engineering, B.S.

**First Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| CHEM 167 | 4 | ENGL 150 | 3 |
| M E 160 | 3 | M E 170 | 3 |
| MATH 165 | 4 | MATH 166 | 4 |
| ENGR 101 | R | PHYS 221 | 5 |
| General Education Elective | 3 | LIB 160 | 1 |
| | **14** | | **16** |

**Second Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| C E 274 | 3 | E M 324 | 3 |
| MAT E 273 | 3 | MATH 267 | 4 |
| MATH 265 | 4 | M E 231 | 3 |
| PHYS 232 | 4 | M E 270 | 3 |
| PHYS 232L | 1 | General Education Elective | 3 |
| ENGL 250 | 3 | M E 202 | R |
| | **18** | | **16** |

**Third Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| E E 442 | 2 | M E 325 | 3 |
| E E 448 | 2 | M E 335 | 4 |
| M E 345 | 3 | M E 370 | 3 |
| M E 332 | 3 | M E 324 | 3 |
| STAT 305 | 3 | Communication Requirement | 3 |
| M E 324L | 1 | | |
| General Education Elective | 3 | | |
| | **17** | | **16** |

**Fourth Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| Gen Ed Elective (Intl Perspective) | 3 | Gen Ed Elective (US Diversity) | 3 |
| M E 421 | 4 | Technical Elective | 3 |
| M E 436 | 4 | Technical Elective | 3 |
| Technical Elective | 3 | Technical Elective | 3 |
| Technical Elective | 3 | Capstone Design | 3 |
| | **17** | | **15** |

# Graduate Study

The department offers programs for the degrees Master of Engineering (M. Eng.), Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) with a major in mechanical engineering. The M.Eng. degree is a coursework-only degree designed to improve professional expertise in mechanical engineering. The M.S. and Ph.D. degrees are designed to improve the student's capability to conduct research as well as their professional expertise. Although co-major and formal minor programs are not offered in mechanical engineering, courses may be used for minor work by students taking major work in other departments.

Well-qualified juniors and seniors in mechanical engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue both the Bachelor of Science and Master of Science, the Bachelor of Science and Master of Business Administration. Under concurrent enrollment, students are eligible for assistantships and simultaneously take undergraduate and graduate courses. Details are available in the Graduate Programs Office and on the department's website (http://www.me.iastate.edu/).

The graduate program offers advanced study in a variety of thrust areas, including biological and nanoscale sciences, clean energy technologies, complex fluid systems, design and manufacturing innovation, and simulation and visualization.

The department offers students the opportunity to broaden their education by participating in minor programs in established departments, interdepartmental programs, or other experiences as approved by their program of study committees.

The requirements for advanced degrees are established by the student's program of study committee within established guidelines of the Graduate College. Graduate students who have not completed an undergraduate program of study substantially equivalent to that required of undergraduate students in the department can expect that additional supporting coursework will be required.

Program requirements can be found on the department webpage (http://www.me.iastate.edu/) and in the Mechanical Engineering Graduate Student Handbook.

**Courses primarily for undergraduates:**

**M E 160: Mechanical Engineering Problem Solving with Computer Applications**
(2-2) Cr. 3. F.S.
*Prereq: M E majors only. MATH 142 or MATH 143 or MATH 145; credit or enrollment in MATH 165.*
Introduction to the field of Mechanical Engineering through problem-solving in a range of topics including statics, mechanics of materials and thermo-fluids. Techniques to professionally present and communicate solutions. Use of MATLAB computer programming to aid problem solving, including curve fitting and graphing. Only one of M E 160, ENGR 160, Aer E 160, C E 160, CPR E 185, E E 185, S E 185 and I E 148 may count towards graduation.

**M E 170: Engineering Graphics and Introductory Design**
(2-2) Cr. 3. F.S.
*Prereq: Satisfactory scores on mathematics placement assessments; credit or enrollment in MATH 142 or MATH 143 or MATH 145*
Integration of fundamental graphics, computer modeling, and engineering design. Applications of multiview drawings and dimensioning. Techniques for visualizing, analyzing, and communicating 3-D geometries. Application of the design process including written and oral reports. Freehand and computer methods.

**M E 190: Learning Communities**
(1-0) Cr. 1. Repeatable. F.S.
Enrollment in M E learning communities.

**M E 202: Mechanical Engineering - Professional Planning**
Cr. R. F.S.
*Prereq: Credit or Enrollment in M E 231*
Preparation for a career in mechanical engineering; discussion of opportunities for leadership, undergraduate research, experiential learning.

**M E 220: Globalization and Sustainability**
(Cross-listed with ANTHR, ENV S, GLOBE, MAT E, SOC). (3-0) Cr. 3. F.S.
An introduction to understanding the key global issues in sustainability. Focuses on interconnected roles of energy, materials, human resources, economics, and technology in building and maintaining sustainable systems. Applications discussed will include challenges in both the developed and developing world and will examine the role of technology in a resource-constrained world. Cannot be used for technical elective credit in any engineering department.
Meets International Perspectives Requirement.

**M E 231: Engineering Thermodynamics I**
(3-0) Cr. 3. F.S.SS.
*Prereq: MATH 166, CHEM 167, PHYS 221*
Fundamental concepts based on zeroth, first and second laws of thermodynamics. Properties and processes for ideal gases and solid-liquid-vapor phases of pure substances. Applications to vapor power cycles.

**M E 270: Introduction to Mechanical Engineering Design**
(1-6) Cr. 3. F.S.
*Prereq: M E 160 or equivalent, M E 170 or equivalent, PHYS 221*
Overview of mechanical engineering design with applications to thermal and mechanical systems. Introduction to current design practices used in industry. Semester-long team project focused on addressing societal needs. Past projects include designing human powered charging systems and products for developing nations.

**M E 324: Manufacturing Engineering**
(3-0) Cr. 3. F.S.SS.
*Prereq: M E 270, E M 324, MAT E 273 and M E 324L*
Fundamentals of manufacturing processes including forming, machining, casting and welding with emphasis on design considerations in manufacturing. Mechanical behavior of metallic materials. Modern manufacturing practices.

**M E 324L: Manufacturing Engineering Laboratory**
(0-2) Cr. 1. F.S.SS.
*Prereq: M E 270, MAT E 273, ENGL 250*
Laboratory exercises in metrology, mechanical testing (tensile/compression and hardness tests), computer aided design (CAD), machining operations, metal welding, metal casting, and bulk/sheet metal forming.

**M E 325: Mechanical Component Design**
(3-0) Cr. 3. F.S.SS.
*Prereq: M E 170, E M 324, and STAT 305*
Philosophy of design and design methodology. Consideration of stresses and failure models useful for static and fatigue loading. Analysis, selection and synthesis of machine elements.

**M E 332: Engineering Thermodynamics II**
(3-0) Cr. 3. F.S.SS.
*Prereq: M E 231*
Gas power cycles. Fundamentals of gas mixtures, psychrometry, and thermochemistry. Applications to one-dimensional compressible flow, refrigeration, air conditioning and combustion processes.

**M E 335: Fluid Flow**
(3-2) Cr. 4. F.S.SS.
*Prereq: M E 345, MATH 265, MATH 266 or MATH 267, credit or enrollment in M E 332.*
Incompressible and compressible fluid flow fundamentals. Dimensional analysis and similitude. Internal and external flow applications. Lab experiments emphasizing concepts in thermodynamics and fluid flow. Written reports are required.

**M E 345: Engineering Dynamics**
(3-0) Cr. 3. F.S.SS.
*Prereq: C E 274, credit or enrollment in MATH 266 or MATH 267*
Particle and rigid body kinematics, Newton's laws of motion, kinetics of plane motion, rigid body problems using work-energy, linear, and angular impulse-momentum principles, vibrations.

**M E 370: Engineering Measurements**
(2-3) Cr. 3. F.S.SS.
*Prereq: E E 442, STAT 305*
Fundamentals of design, selection, and operation of components of measuring systems. Measurement processes, data acquisition systems, analysis of data, and propagation of measurement uncertainty.

**M E 396: Summer Internship**
Cr. R. Repeatable. SS.
*Prereq: Permission of department and Engineering Career Services*
Professional work period of at least 10 weeks during the summer. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

**M E 398: Cooperative Education (Co-op).**
Cr. R. Repeatable. F.S.
*Prereq: Permission of department and Engineering Career Services*
Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

**M E 401: Human Centered Design, Pre-Departure Course.**
Cr. 1. Alt. S., offered irregularly.
*Prereq: Acceptance into Study Abroad Program.*
A pre-departure course for M E 402. Safety and health issues while on site; travel logistics; required travel documents and deadlines; cultural norms. Offered on a satisfactory-fail basis only.

**M E 402: Field Engineering: Human Centered Design Concepts.**
(1-4) Cr. 3. Alt. SS., offered irregularly.
*Prereq: M E 401*
Design methodology and field engineering principles for use in engineering problem solving in developing nations; application of principals will be on site. Awareness of culture, use of local artisans, crafts people and engineers will be emphasized for the purpose of ensuring sustainable and appropriate technology.
Meets International Perspectives Requirement.

**M E 410: Mechanical Engineering Applications of Mechatronics**
(2-2) Cr. 3. Alt. S., offered irregularly.
*Prereq: E E 442, E E 448, credit or enrollment in M E 421*
Fundamentals of sensor characterization, signal conditioning and motion control, coupled with concepts of embedded computer control. Digital and analog components used for interfacing with computer controlled systems. Mechanical system analysis combined with various control approaches. Focus on automation of hydraulic actuation processes. Laboratory experiences provide hands-on development of mechanical systems.

**M E 411: Automatic Controls**
(2-2) Cr. 3. F.
*Prereq: M E 421*
Methods and principles of automatic control. Pneumatic, hydraulic, and electrical systems. Representative applications of automatic control systems. Mathematical analysis of control systems.

**M E 412: Ethical Responsibilities of a Practicing Engineer**
(3-0) Cr. 3. F.
*Prereq: Credit or enrollment in M E 325*
The study of ethics in engineering design and the engineering profession. A comprehensive look at when ethical decisions must be made and an approach to make them. The approach takes into account moral, legal, technical, experiential, and standards to aid in ethical decision making. Each area will be studied through lectures, debates, guest speakers, class discussion, and case studies.

**M E 413: Fluid Power Engineering**
(Cross-listed with A B E). (2-2) Cr. 3. F.
*Prereq: Credit or enrollment in E M 378 or M E 335, A B E 216 or M E 270*
Fundamental fluid power principles, symbols and schematics. Hydraulic fluid properties. Function and performance of components such as connections and fittings, filtration, pumps, valves, actuators, hydrostatic transmissions. Hydraulic system dynamics. Modeling and simulation of circuits. Analysis and design of hydraulic systems. Hydrostatic transmission design. Hands-on construction of circuits, measurement of system variables, and electrohydraulic control.

**M E 415: Mechanical Systems Design**
(0-6) Cr. 3. F.S.
*Prereq: M E 324, M E 325*
Mechanical Engineering Capstone Design course. Team approach to solving design problems involving mechanical systems. Teams will use current design practices they will encounter in industry. Document decisions concerning form and function, material specification, manufacturing methods, safety, cost, and conformance with codes and standards. Solution description includes oral and written reports. Projects often worked with industry sponsors.

**M E 416: Mechanism Design and Analysis**
Cr. 3. S.
*Prereq: M E 325*
An introduction to the design and analysis of mechanisms and the use of prescribed design methodologies to identify design requirements and achieve desired motion profiles. Topics include fundamental mechanism kinematics; graphical and analytical mechanism synthesis methods; velocity and acceleration analysis; and the design of linkages, cams and gear trains. Significant amount of team-based problem solving and the development of physical and computational models to assist in the design process.

**M E 417: Advanced Machine Design**
(Dual-listed with M E 517). (3-0) Cr. 3. F.
*Prereq: M E 325, MAT E 273*
Stress life, strain life, and fracture mechanics approaches to fatigue life and design with metals, polymers and ceramics. Introduction to material selection in design of machine components. Thermal and structural considerations in design of machine components and hybrid materials. Course project and relevant literature review required for graduate credit.

**M E 418: Mechanical Considerations in Robotics**
(Dual-listed with M E 518). (3-0) Cr. 3. S.
*Prereq: Credit or enrollment in M E 421*
Three dimensional kinematics, dynamics, and control of robot manipulators, hardware elements and sensors. Laboratory experiments using industrial robots.

**M E 419: Computer-Aided Design**
(3-0) Cr. 3. F.S.
*Prereq: M E 325*
Theory and applications of computer- aided design. Computer graphics programming, solid modeling, assembly modeling, and finite element modeling. Mechanical simulation, process engineering, rapid prototyping and manufacturing integration.

**M E 421: System Dynamics and Control**
(3-2) Cr. 4. F.S.SS.
*Prereq: E E 442, E E 448, M E 345, MATH 267*
Modeling and simulation of mechanical, electrical, fluid, and/or thermal systems. Development of equations of motion and dynamic response characteristics in time and frequency domains. Fundamentals of classical control applications, including mathematical analysis and design for closed loop control systems. Introduction to computer interfacing for simulation, data acquisition, and control. Laboratory exercises for hands-on system investigation and control implementation.

**M E 425: Optimization Methods for Complex Designs**
(Dual-listed with M E 525). (3-0) Cr. 3. F.
*Prereq: M E 160, MATH 265*
Optimization involves finding the 'best' according to specified criteria. Review of a range of optimization methods from traditional nonlinear to modern evolutionary methods such as Genetic algorithms. Examination of how these methods can be used to solve a wide variety of design problems across disciplines, including mechanical systems design, biomedical device design, biomedical imaging, and interaction with digital medical data. Students will gain knowledge of numerical optimization algorithms and sufficient understanding of the strengths and weaknesses of these algorithms to apply them appropriately in engineering design. Experience includes code writing and off-the-shelf routines. Numerous case-studies of real-world situations in which problems were modeled and solved using advanced optimization techniques.

**M E 427: Vehicle Dynamics and Suspension Design**
Cr. 3. Alt. S., offered odd-numbered years.
*Prereq: M E 345*
Analysis and evaluation of the performance of cars, trucks and other surface vehicles. Computer simulation of ride, braking, and directional response. Considerations in the design and fabrication of suspension systems.

**M E 433: Alternative Energy**
(3-0) Cr. 3. F.
*Prereq: PHYS 221 and PHYS 232 and Phys 232L and CHEM 167*
Basic principles, performance, and cost analysis of alternative energy systems including biofuels, bioenergy, wind, solar, fuel cells, storage and other alternative energy systems. Performance analysis and operating principles of systems and components, and economic analysis for system design and operation will be taught. Emphasis is on alternative energy technologies needed to meet our future energy needs at various scales ranging from household to city to national levels.

**M E 436: Heat Transfer**
(3-2) Cr. 4. F.S.SS.
*Prereq: M E 335*
Heat transfer by conduction, convection, and radiation. Similarity concepts in heat, mass, and momentum transfer. Methods for determination of heat transfer coefficients. Combined modes of heat transfer. Heat exchangers. Lab experiments emphasizing concepts in thermodynamics and heat transfer. Written reports are required.

**M E 437: Introduction to Combustion Engineering**
(3-0) Cr. 3. S.
*Prereq: Credit in M E 332 or equivalent.*
Introduction to the fundamentals of combustion and the analysis of combustion systems for gaseous, liquid, and solid fuels-including biomass fuels. Combustion fundamentals are applied to the analysis of engines; turbines, biomass cookstoves; suspension, fixed-bed, and fluidized-bed furnaces; and other combustion devices.

**M E 441: Fundamentals of Heating, Ventilating, and Air Conditioning**
(3-0) Cr. 3. F.
*Prereq: Credit or enrollment in M E 436*
Space conditioning and moist air processes. Application of thermodynamics, heat transfer, and fluid flow principles to the analysis of heating, ventilating, and air conditioning components and systems. Performance and specification of components and systems.

**M E 442: Heating and Air Conditioning Design**
(1-5) Cr. 3. S.
*Prereq: M E 441 or with Instructor Permission*
Design criteria and assessment of building environment and energy requirements. Design of heating, ventilating, and air conditioning systems. System control and economic analysis. Oral and written reports required.

**M E 444: Elements and Performance of Power Plants**
(3-0) Cr. 3. S.
*Prereq: M E 332, credit or enrollment in M E 335*
Basic principles, thermodynamics, engineering analysis of power plant systems. Topics include existing power plant technologies, the advanced energyplex systems of the future, societal impacts of power production, and environmental and regulatory concerns.

**M E 448: Fluid Dynamics of Turbomachinery**
(Cross-listed with AER E). (3-0) Cr. 3. S.
*Prereq: AER E 311 or M E 335*
Applications of principles of fluid mechanics and thermodynamics in performance analysis and design of turbomachines. Conceptual and preliminary design of axial and radial flow compressors and turbines using velocity triangles and through-flow approaches.

**M E 449: Internal Combustion Engines**
(3-1) Cr. 3. F.
*Prereq: M E 332*
Basic principles, thermodynamics, combustion, and exhaust emissions of spark-ignition and compression-ignition engines. Laboratory determination of fuel properties and engine performance. Effects of engine components and operating conditions on performance. Written reports required.

**M E 451: Engineering Acoustics**
(Cross-listed with E E, E M). (2-2) Cr. 3. Alt. S., offered even-numbered years.
*Prereq: PHYS 221 and MATH 266 or MATH 267*
The basics of acoustic wave propagation in fluids with an emphasis on sound propagation in air. Topics include transmission and reflection of sound at a boundary; role of acoustic sources in directing sound fields; diffraction of sound around solid objects; reverberation of sound in a room; and the measurement of sound fields.

**M E 456: Machine Vision**
(Dual-listed with M E 556). Cr. 3. Repeatable. Alt. F., offered odd-numbered years.
*Prereq: MATH 317, M E 421 or permission of instructor*
Practical imaging processing techniques, geometric optics, and mathematics behind machine vision, as well as the most advanced 3D vision techniques. Experience with practical vision system development and analysis. Assignments include individual bi-weekly homework; weekly readings and lectures; and a semester-long research project on design and experiment vision systems.

**M E 466: Multidisciplinary Engineering Design**
(Cross-listed with A B E, AER E, B M E, CPR E, E E, ENGR, I E, MAT E). (1-4) Cr. 3. Repeatable. F.S.
*Prereq: Student must be within two semesters of graduation; permission of instructor.*
Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

**M E 467: Multidisciplinary Engineering Design II**
(Cross-listed with AER E, ENGR, I E, MAT E). (1-4) Cr. 3. Repeatable, maximum of 2 times. Alt. F., offered irregularly.Alt. S., offered irregularly.
*Prereq: Student must be within two semesters of graduation or receive permission of instructor.*
Build and test of a conceptual design. Detail design, manufacturability, test criteria and procedures. Application of design tools such as CAD and CAM and manufacturing techniques such as rapid prototyping. Development and testing of a full-scale prototype with appropriate documentation in the form of design journals, written reports, oral presentations and computer models and engineering drawings.

**M E 475: Modeling and Simulation**
(3-0) Cr. 3. S.
*Prereq: M E 421, credit or enrollment in M E 436*
Introduction to computer solution techniques required to simulate flow, thermal, and mechanical systems. Methods of solving ordinary and partial differential equations and systems of algebraic equations; interpolation, numerical integration; finite difference and finite element methods.

**M E 484: Technology, Globalization and Culture**
(Dual-listed with M E 584). (Cross-listed with WLC). (3-0) Cr. 3. F.
*Prereq: junior or senior classification for M E 484; graduate classification for M E 584*
Cross-disciplinary examination of the present and future impact of globalization with a focus on preparing students for leadership roles in diverse professional, social, and cultural contexts. Facilitate an understanding of the threats and opportunities inherent in the globalization process as they are perceived by practicing professionals and articulated in debates on globalization. Use of a digital forum for presenting and analyzing globalization issues by on-campus and off-campus specialists.
Meets International Perspectives Requirement.

**M E 490: Independent Study**
Cr. 1-6. Repeatable.
Investigation of topics holding special interest of students and faculty. Election of course and topic must be approved in advance by supervising faculty.

**M E 490H: Independent Study: Honors**
Cr. 1-6. Repeatable.
Investigation of topics holding special interest of students and faculty. Election of course and topic must be approved in advance by supervising faculty.

**M E 490N: Independent Study: Non Technical Elective**
Cr. 1-6. Repeatable.
Investigation of topics holding special interest of students and faculty. Election of course and topic must be approved in advance by supervising faculty.

**M E 490T: Independent Study: Technical Elective**
Cr. 1-6. Repeatable.
Investigation of topics holding special interest of students and faculty. Election of course and topic must be approved in advance by supervising faculty.

**Courses primarily for graduate students, open to qualified undergraduates:**

**M E 501: Fundamentals of Biorenewable Resources**
(3-0) Cr. 3. S.
*Prereq: Previous coursework in introductory physics and chemistry is recommended.*
Introduction to the science and engineering of converting biorenewable resources into bioenergy and biobased products. Survey of biorenewable resource base and properties; description of biofuels and biobased products; production of biorenewable resources; processing technologies for fuels, chemicals, materials, and energy; environmental impacts; technoeconomic analysis of production and processing; and biofuels policy.

**M E 502: Microfluidics and Nanofluidics: Theory, Design and Devices**
Cr. 3. Alt. S., offered even-numbered years.
*Prereq: M E 436 (Heat Transfer) or an undergraduate class on transport phenomena, or Instructor's permission*
Analysis of transport phenomena and its application to the field of microfluidics. Conservation equations of mass, momentum and energy are derived from first principles and applied to contemporary topics in microfluidics such as organs-on-a-chip, point-of-care and separation processes. The conservation equations are used to model hydrodynamics and random walk diffusion of multiphase microfluidic systems. Advanced microfluidic topics, such as interfacial transport involving capillary interactions, electrostatic forces, and chemical gradients are discussed into order to describe a variety of phenomena observed in microfluidic devices. Numerical models based on finite element modeling and molecular dynamic simulation techniques are discussed as one approach to designing microfluidic devices such as pumps, micromixers, actuators, and filters.

**M E 510: Economics and Policy of Engineered Energy Systems**
Cr. 3. Alt. F., offered even-numbered years.
*Prereq: Graduate standing.*
Economics and policy for U.S. energy systems, with an emphasis on connections to engineering. Topics include: economic analysis of conventional energy commodity markets and technologies, deregulated electricity markets, and emerging energy technologies; demand forecasting; economic and environmental policy in energy; integrated assessment; and semester-specific contemporary issues. Economics majors may not apply this course towards graduation.

**M E 511: Advanced Control Design**
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 411*
Application of control design methods using continuous, discrete, and frequency-based models. Approaches include classical, pole assignment, model reference, internal model, and adaptive control methods. Mechanical design projects.

**M E 517: Advanced Machine Design**
(Dual-listed with M E 417). (3-0) Cr. 3. F.
*Prereq: M E 325, MAT E 273*
Stress life, strain life, and fracture mechanics approaches to fatigue life and design with metals, polymers and ceramics. Introduction to material selection in design of machine components. Thermal and structural considerations in design of machine components and hybrid materials. Course project and relevant literature review required for graduate credit.

**M E 518: Mechanical Considerations in Robotics**
(Dual-listed with M E 418). (3-0) Cr. 3. S.
*Prereq: Credit or enrollment in M E 421*
Three dimensional kinematics, dynamics, and control of robot manipulators, hardware elements and sensors. Laboratory experiments using industrial robots.

**M E 520: Material and Manufacturing Considerations in Design**
(3-0) Cr. 3. Alt. F., offered irregularly.
*Prereq: M E 324, M E 325*
Integration of materials, design and manufacturing. Materials selection. Design for assembly and manufacturing (DFMA). Design and redesign to facilitate cost-effective manufacturing using material selection and DFMA software.

**M E 521: Mechanical Behavior and Manufacturing of Polymers and Composites**
(Cross-listed with M S E). (3-0) Cr. 3. S.
*Prereq: M E 324 or MAT E 272 and E M 324*
Effect of chemical structure and morphology on properties. Linear viscoelasticity, damping and stress relaxation phenomena. Structure and mechanics of filler and fiber reinforced composites. Mechanical properties and failure mechanisms. Material selection and designing with polymers. Processing of polymer and composite parts.

**M E 525: Optimization Methods for Complex Designs**
(Dual-listed with M E 425). (3-0) Cr. 3. F.
*Prereq: M E 160, MATH 265*
Optimization involves finding the 'best' according to specified criteria. Review of a range of optimization methods from traditional nonlinear to modern evolutionary methods such as Genetic algorithms. Examination of how these methods can be used to solve a wide variety of design problems across disciplines, including mechanical systems design, biomedical device design, biomedical imaging, and interaction with digital medical data. Students will gain knowledge of numerical optimization algorithms and sufficient understanding of the strengths and weaknesses of these algorithms to apply them appropriately in engineering design. Experience includes code writing and off-the-shelf routines. Numerous case-studies of real-world situations in which problems were modeled and solved using advanced optimization techniques.

**M E 527: Mechanics of Machining and Finishing Processes**
(3-0) Cr. 3. Alt. F., offered even-numbered years.
*Prereq: M E 324*
Mechanics of material removal for ductile materials. Shear zone theory. Oblique cutting. Heat transfer in machining. Milling and grinding. Mechanics of material removal for brittle materials. Optimal selection and design of cutting parameters. Control of machining processes. Principles of precision finishing. Design considerations for machining and finishing processes.

**M E 528: Micro/Nanomanufacturing**
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 324*
Concepts and applications of micro/nanotechnology appropriate to the manufacturing field. An overview of micro/nano-fabrication techniques including mechanical, EDM, laser and lithography. MEMS device fabrication. Scaling laws. Top down and bottom up approaches of nanomanufacturing. Experimental or theoretical project leading to potential submission of a manuscript for journal or conference.

**M E 530: Advanced Thermodynamics**
(3-0) Cr. 3. F.
*Prereq: M E 332*
Fundamentals of thermodynamics from the classical viewpoint with emphasis on the use of the first and second laws for analysis of thermal systems. Generalized thermodynamic relationships. Computer applications of thermodynamic properties and system analysis. Selected topics.

**M E 531: Advanced Energy Systems and Analysis**
Cr. 3. S.
*Prereq: M E 231 or M E 332 or graduate standing or instructor permission*
Introduction to energy systems including economic and thermodynamic principles. Various production systems will be analyzed. Application to transportation and building systems will be emphasized. Sustainability, climate change and other current energy system topics.

**M E 532: Compressible Fluid Flow**
(Cross-listed with AER E). (3-0) Cr. 3. S.
*Prereq: AER E 310, 311 or equivalent*
Thermodynamics of compressible flow. Viscous and inviscid compressible flow equations. One dimensional steady flow; isentropic flow, shocks, expansions. Multidimensional compressible flow aspects. Linear and nonlinear wave analysis and method of characteristics. Subsonic, transonic, supersonic and hypersonic flows.

**M E 534: Energetic Materials Combustion and Systems**
Cr. 3. Alt. S., offered even-numbered years.
*Prereq: M E 231; MATH 267; M E 335 or AER E 310 Recommend: M E 436; AER E 311; M E 437 or M E 542*
Introduction to energetic materials (classes of energetics, their use, safety, analysis of multiphase deflagration/detonation reaction wave structures), their application (e.g. pyrotechnics, chemical propulsion systems, explosives), system performance analysis, common measurement techniques, and societal/environmental implications.

**M E 535: Thermochemical Processing of Biomass**
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 332 or graduate status*
Introduction to thermal and catalytic processes for the conversion of biomass to biofuels and other biobased products. Topics include gasification, fast pyrolysis, hydrothermal processing, syngas to synfuels, and bio-oil upgrading. Application of thermodynamics, heat transfer, and fluid dynamics to bioenergy and biofuels.

**M E 536: Advanced Heat Transfer**
(3-0) Cr. 3. S.
*Prereq: M E 436*
Advanced treatment of heat transmission by conduction, convection, and radiation.

**M E 538: Advanced Fluid Flow**
(3-0) Cr. 3. F.
*Prereq: Credit or enrollment in M E 436*
Detailed analysis of incompressible/compressible, viscous/inviscid, laminar/turbulent, and developing fluid flows on a particle/point control volume basis.

**M E 542: Advanced Combustion**
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 332 or CH E 381*
Thermochemistry and transport theory applied to combustion. Gas phase equilibrium. Energy balances. Reaction kinetics. Flame temperatures, speed, ignition, and extinction. Premixed and diffusion flames. Combustion aerodynamics. Mechanisms of air pollution.

**M E 543: Introduction to Random Vibrations and Nonlinear Dynamics**
(Cross-listed with E M). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Vibrations of continuous systems. Nonlinear vibration phenomena, perturbation expansions; methods of multiple time scales and slowly-varying amplitude and phase. Characteristics of random vibrations; random processes, probability distributions, spectral density and its significance, the normal or Gaussian random process. Transmission of random vibration, response of simple single and two-degree-of-freedom systems to stationary random excitation. Fatigue failure due to random excitation.

**M E 545: Thermal Systems Design**
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
*Prereq: M E 436*
Integrating thermodynamics, fluid mechanics, and heat transfer to model thermal equipment and to simulate thermal systems. Second law and parametric analysis; cost estimation, life cycle analysis and optimization. Some computer programming required.

**M E 546: Computational Fluid Mechanics and Heat Transfer I**
(Cross-listed with AER E). (3-0) Cr. 3. F.
*Prereq: AER E 310 or M E 335, and programming experience*
Basic concepts of discretization, consistency, and stability. Explicit and implicit methods for ordinary differential equations. Methods for each type of partial differential equation. Iterative solution methods; curvilinear grids. Students will program basic algorithms.

**M E 547: Computational Fluid Mechanics and Heat Transfer II**
(Cross-listed with AER E). (3-0) Cr. 3. S.
*Prereq: AER E 546 or equivalent*
Application of computational methods to current problems in fluid mechanics and heat transfer. Methods for solving the Navier-Stokes and reduced equation sets such as the Euler, boundary layer, and parabolized forms of the conservation equations. Introduction to relevant aspects of grid generation and turbulence modeling.

**M E 550: Advanced Biosensors: Fundamentals and Applications**
Cr. 3. Alt. F., offered even-numbered years.
*Prereq: Graduate status or Advanced undergraduates (junior or senior). Recommend a basic background in engineering and one or more introductory biology courses.*
Extensive overview of biosensors including biological/biomedical microelectromechanical (Bio-MEMs) systems and bioanalytical devices with an introduction to fundamental principles, detection methods, and miniaturization techniques. Fundamental biosensor theory including biorecognition, transduction, signal acquisition, and post processing/data analysis will be discussed. Distinct sensing modalities (e.g., electrochemical, optical, thermal and mass based), biorecognition agents (e.g., enzymes, antibodies, aptamers, whole cells/tissues, genetically engineered proteins) and advanced transduction materials (e.g., carbon nanotubes, graphene, quantum/carbon dots, and polymers/hydrogels) and their use in the context of specific applications (e.g., biomedical, environmental, food safety) will be reviewed in detail. Additionally, students will design a theoretical biosensor and present their design in a written proposal and oral presentation.

**M E 552: Advanced Acoustics**
(Cross-listed with E M). (3-0) Cr. 3. Alt. F., offered irregularly.
*Prereq: E M 451*
Theoretical acoustics: wave propagation in fluids; acoustic radiation, diffraction and scattering; nonlinear acoustics; radiation force; cavitation; and ray acoustics.

**M E 556: Machine Vision**
(Dual-listed with M E 456). Cr. 3. Repeatable. Alt. F., offered odd-numbered years.
*Prereq: MATH 317, M E 421 or permission of instructor*
Practical imaging processing techniques, geometric optics, and mathematics behind machine vision, as well as the most advanced 3D vision techniques. Experience with practical vision system development and analysis. Assignments include individual bi-weekly homework; weekly readings and lectures; and a semester-long research project on design and experiment vision systems.

**M E 557: Computer Graphics and Geometric Modeling**
(Cross-listed with COM S, CPR E). (3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 421 or instructor permission*
Fundamentals of computer graphics technology. Data structures. Parametric curve and surface modeling. Solid model representations. Applications in engineering design, analysis, and manufacturing.

**M E 561: Scanning Probe Microscopy**
(2-2) Cr. 3. Alt. F., offered irregularly.
*Prereq: First year physics, chemistry*
Introduction to the scanning probe microscope (SPM, also known as atomic force microscope or AFM) and associated measurement techniques. Overview or instrumentation system, basic principles of operation, probe-sample interaction and various operational modes to obtain micro/nanoscale structure and force spectroscopy of material surfaces. Examples of SPM significance and applications in science and engineering research, nanotechnology and other industries. Laboratory work involving use of a scanning probe microscope system is an integral part of the course.

**M E 563: Micro and Nanoscale Mechanics**
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
*Prereq: E M 324 and M E 325*
Review of Fundamentals: (Elasticity, Electromagnetism, Mechanical response), Mechanics of thermally, electrostatically and magnetically actuated microsystems, Mechanics and design of nanostructured materials, mechanics of surface stress engineering and its implications to sensors and thin film structures.

**M E 564: Fracture and Fatigue**
(Cross-listed with AER E, E M, M S E). (3-0) Cr. 3. Alt. F., offered even-numbered years.
*Prereq: E M 324 and either MAT E 216 or MAT E 273 or MAT E 392. Undergraduates: Permission of instructor*
Materials and mechanics approach to fracture and fatigue. Fracture mechanics, brittle and ductile fracture, fracture and fatigue characteristics, fracture of thin films and layered structures. Fracture and fatigue tests, mechanics and materials designed to avoid fracture or fatigue.

**M E 566: Phase Transformation in Elastic Materials**
(Cross-listed with E M). (3-0) Cr. 3. S.
*Prereq: EM 510 or EM 516 or EM 514*
Continuum thermodynamics and kinetics approaches to phase transformations. Phase field approach to stress- and temperature-induced martensitic transformations and twinning at the nanoscale. Nucleation and growth. Nanostructural evaluation. Analytical and numerical solutions. Surface stresses and energy. Surface-induced phase transformations. Large Strain formulation.

**M E 570: Solid Modeling and GPU Computing**
Cr. 3. Alt. F., offered even-numbered years.
*Prereq: M E 170 and M E 419, or Instructor Permission*
Theory and applications of solid modeling and introduction to parallel computing using the graphic processing unit (GPU). Topics include solid modeling fundamentals, representations of solid geometry, introduction to parallel programming using CUDA, and applications of GPU algorithms. Design and analysis software include SolidWorks and programming using either C or Python, and NVIDIA CUDA.

**M E 573: Random Signal Analysis and Kalman Filtering**
(Cross-listed with AER E, E E). (3-0) Cr. 3. F.
*Prereq: E E 324 or AER E 331 or M E 370 or M E 411 or MATH 341*
Elementary notions of probability. Random processes. Autocorrelation and spectral functions. Estimation of spectrum from finite data. Response of linear systems to random inputs. Discrete and continuous Kalman filter theory and applications. Smoothing and prediction. Linearization of nonlinear dynamics.

**M E 574: Optimal Control**
(Cross-listed with AER E, E E). (3-0) Cr. 3. S.
*Prereq: E E 577*
The optimal control problem. Variational approach. Pontryagin's principle, Hamilton-Jacobi equation. Dynamic programming. Time-optimal, minimum fuel, minimum energy control systems. The regulator problem. Structures and properties of optimal controls.

**M E 575: Introduction to Robust Control**
(Cross-listed with AER E, E E). (3-0) Cr. 3.
*Prereq: E E 577*
Introduction to modern robust control. Model and signal uncertainty in control systems. Uncertainty description. Stability and performance robustness to uncertainty. Solutions to the H2, Hoo, and l1 control problems. Tools for robustness analysis and synthesis.

**M E 576: Digital Feedback Control Systems**
(Cross-listed with AER E, E E). (3-0) Cr. 3. F.
*Prereq: E E 475 or AER E 432 or M E 411 or MATH 415; and MATH 267*
Sampled data, discrete data, and the z-transform. Design of digital control systems using transform methods: root locus, frequency response and direct design methods. Design using state-space methods. Controllability, observability, pole placement, state estimators. Digital filters in control systems. Microcomputer implementation of digital filters. Finite wordlength effects. Linear quadratic optimal control in digital control systems. Simulation of digital control systems.

**M E 577: Linear Systems**
(Cross-listed with AER E, E E, MATH). (3-0) Cr. 3. F.
*Prereq: E E 324 or AER E 331 or MATH 415; and MATH 207*
Linear algebra review. Least square method and singular value decomposition. State space modeling of linear continuous-time systems. Solution of linear systems. Controllability and observability. Canonical description of linear equations. Stability of linear systems. State feedback and pole placements. Observer design for linear systems.

**M E 578: Nonlinear Systems**
(Cross-listed with AER E, E E, MATH). (3-0) Cr. 3. S.
*Prereq: E E 577*
Linear vs nonlinear systems. Phase plane analysis. Bifurcation and center manifold theory. Lyapunov stability. Absolute stability of feedback systems. Input-output stability. Passivity theory and feedback linearization. Nonlinear control design techniques.

**M E 580: Virtual Environments, Virtual Worlds, and Application**
(Cross-listed with HCI). (3-0) Cr. 3. Alt. S., offered even-numbered years.
*Prereq: Senior or Graduate status.*
A systematic introduction to the underpinnings of Virtual Environments (VE), Virtual Worlds, advanced displays and immersive technologies; and an overview of some of the applications areas particularly virtual engineering.

**M E 584: Technology, Globalization and Culture**
(Dual-listed with M E 484). (Cross-listed with WLC). (3-0) Cr. 3. F.
*Prereq: junior or senior classification for M E 484; graduate classification for M E 584*
Cross-disciplinary examination of the present and future impact of globalization with a focus on preparing students for leadership roles in diverse professional, social, and cultural contexts. Facilitate an understanding of the threats and opportunities inherent in the globalization process as they are perceived by practicing professionals and articulated in debates on globalization. Use of a digital forum for presenting and analyzing globalization issues by on-campus and off-campus specialists.
Meets International Perspectives Requirement.

**M E 585: Fundamentals of Predictive Plant Phenomics**
(Cross-listed with BCB, GDCB). Cr. 4. F.
Principles of engineering, data analysis, and plant sciences and their interplay applied to predictive plant phenomics. Transport phenomena, sensor design, image analysis, graph models, network data analysis, fundamentals of genomics and phenomics. Multidisciplinary laboratory exercises.

**M E 590: Special Topics**
Cr. 1-8. Repeatable.

**M E 590Q: Special Topics: Independent Literature Investigation**
Cr. 1-8. Repeatable.

**M E 590T: Special Topics: Biological and Nanoscale Sciences**
Cr. 1-8. Repeatable.

**M E 590U: Special Topics: Complex Fluid Systems**
Cr. 1-8. Repeatable.

**M E 590V: Special Topics: Clean Energy Technologies**
Cr. 1-8. Repeatable.

**M E 590W: Special Topics: Design and Manufacturing Innovation**
Cr. 1-8. Repeatable.

**M E 590Z: Special Topics: Simulation and Visualization**
Cr. 1-8. Repeatable.

**M E 591: Probabilistic Engineering Analysis and Design**
Cr. 3. Alt. S., offered even-numbered years.
*Prereq: Linear algebra or MATH 207; probability theory or STAT 231; or instructor permission*
Applications of probabilistic and statistical methods to engineering system design and post-design failure prognostics. Hands-on learning of various probabilistic and statistical design methods, such as design of experiments, surrogate modeling, uncertainty quantification, reliability-based design, and robust design. It also covers Bayesian estimation and machine learning methods for post-design failure prognostics.

**M E 592: Data Analytics and Machine Learning for Cyber-Physical Systems Applications**
Cr. 3. S.
*Prereq: Basics of linear algebra, probability theory and computer programming*
In this course, several data analytics techniques and Machine Learning algorithms will be explored with a strong focus on various applications to cyber-physical systems. The students will have hands-on experience with various analytics tools and data-driven decision-making techniques applied to a diverse set of spatial, temporal and spatiotemporal data emanating from real-life cyber-physical systems such as robots, energy & power systems, design & manufacturing systems, self-driving cars and agricultural systems. Among various machine learning techniques, special emphasis will be given on deep learning, reinforcement learning and probabilistic graphical models. A key highlight of this course is that the assignments and class projects will be designed for individual students or groups based on their specific applications or data sets of interest.

**M E 599: Creative Component**
Cr. arr. Repeatable.

**Courses for graduate students:**

**M E 600: Seminar**
Cr. R. Repeatable.
(1-0).

**M E 625: Surface Modeling**
(3-0) Cr. 3. Alt. F., offered odd-numbered years.
*Prereq: M E 557 or instructor permission*
Theory and implementation of contemporary parametric sculptured surface modeling technology. Non-uniform rational B-spline (NURBS) curves and surfaces. Fundamental computational algorithms. Construction techniques. Advanced modeling topics. Computer projects.

**M E 632: Multiphase Flow**
(Cross-listed with CH E). (3-0) Cr. 3. Alt. S., offered even-numbered years.
*Prereq: M E 538*
Single particle, mutliparticle and two-phase fluid flow phenomena (gas-solid, liquid-solid and gas-liquid mixtures); particle interactions, transport phenomena, wall effects; bubbles, equations of multiphase flow. Dense phase (fluidized and packed beds) and ducted flows; momentum, heat and mass transfer. Computer solutions.

**M E 637: Convection Heat Transfer**
(3-0) Cr. 3. Alt. F., offered irregularly.
*Prereq: M E 436*
Convection heat transfer to internal or external flows under laminar or turbulent conditions. Dimensionless parameters. Classical solutions of Newtonian viscous flows. Forced and free convection. Special topics.

**M E 638: Radiation Heat Transfer**
(3-0) Cr. 3. Alt. F., offered irregularly.
*Prereq: M E 436*
Techniques for analysis of radiation in enclosures. Radiative properties of surfaces. Radiative transfer in participating media. Combined modes of transfer. Approximate methods of analysis.

**M E 647: Advanced Computational Fluid Dynamics**
(Cross-listed with AER E). (3-0) Cr. 3. S.
*Prereq: AER E 547*
An examination of current methods in computational fluid dynamics. Differencing strategies. Advanced solution algorithms for unstructured meshes. Grid generation. Construction of higher-order CFD algorithms. Parallel computing. Current applications. Use of state of the art CFD codes.

**M E 690: Advanced Topics**
Cr. arr. Repeatable.
Investigation of advanced topics of special interest to graduate students in mechanical engineering.

**M E 690G: Advanced Topics: Advanced Machine Design**
Cr. arr. Repeatable.
Investigation of advanced topics of special interest to graduate students in mechanical engineering.

**M E 690O: Advanced Topics: Engineering Computation**
Cr. arr. Repeatable.
Investigation of advanced topics of special interest to graduate students in mechanical engineering.

**M E 690Q: Advanced Topics: Independent Literature Investigation**
Cr. arr. Repeatable.
Investigation of advanced topics of special interest to graduate students in mechanical engineering.

**M E 690T: Advanced Topics: Biological and Nanoscale Sciences**
Cr. arr. Repeatable. F.S.SS.
Investigation of Special Topics: Biological and Nanoscale Sciences of special interest to graduate students in mechanical engineering.

**M E 690U: Advanced Topics: Complex Fluid Systems**
Cr. arr. Repeatable. F.S.SS.
Investigation of Special Topics: Complex Fluid Systems of special interest to graduate students in mechanical engineering.

**M E 690V: Advanced Topics: Clean Energy Technologies**
Cr. arr. F.S.SS.
Investigation of Special Topics: Clean Energy Technologies of special interest to graduate students in mechanical engineering.

**M E 690W: Advanced Topics: Design and Manufacturing Innovation**
Cr. arr. Repeatable.
Investigation of Design & Manufacturing Innovation of special interest to graduate students in mechanical engineering.

**M E 690Z: Advanced Topics: Simulation and Visualization**
Cr. arr. Repeatable. F.S.SS.
Investigation of Special Topics: Simulation and Visualization of special interest to graduate students in mechanical engineering.

**M E 697: Engineering Internship**
Cr. R. Repeatable.
*Prereq: Permission of Director of Graduate Education, graduate classification*
One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

**M E 699: Research**
Cr. arr. Repeatable.
Offered on a satisfactory-fail basis only.