MECHANICAL ENGINEERING

Our Website (http://www.me.vt.edu)

Nature of the Profession

Mechanical engineering is the broadest of the engineering professions. Because of the breadth of the ME discipline, mechanical engineers work in a wide variety of technical areas and are employed in a range of job functions. Specialty areas within the mechanical engineering discipline include, among many others, acoustics, biomechanics, CAD, controls, energy conversion and energy management, HVAC, materials, mechanical design, mechatronics, nuclear engineering, robotics and automation, and turbomachinery. The actual job functions which mechanical engineers perform vary widely as well. ME's work in design, research and development, manufacturing, service and maintenance, as well as technical sales, in almost every industry. Many are in management and administration. Many mechanical engineering graduates go on to more advanced degrees, or continue their education in other fields, such a law or business.

Employment Opportunities

Because of the diversity and breadth of the mechanical engineering profession, ME graduates find employment in a wide variety of industries, laboratories, and consulting firms. This results in a relatively stable job market that is not dependent upon a single particular industry. The textile, petroleum, chemical, electronic, automotive, aerospace, power generation, HVAC, and manufacturing industries hire large numbers of mechanical engineering graduates and the starting salaries for ME's are very competitive with the other engineering disciplines.

Because of the wide diversity of specialties and job functions any two mechanical engineers might have significantly different day-to-day activities and responsibilities. Some may be concerned with very large engineering systems while others are working with small and even microscale devices and components; some work might call for highly analytical or mathematical approaches while other work might be more amenable to experimental or empirical approaches. Mechanical engineers may be involved in the operation of processing plants, or the design of engines, prosthetic devices, steam and gas turbines or compressors and pumps, alternative fuel devices, and many other devices and systems. At Virginia Tech there is a close association between the ME departments research and design project activities with industry. This enhances the opportunities for student interaction with industry representatives.

Accreditation, Program Educational Objectives, and Student Learning Outcomes

The Bachelor of Science in Mechanical Engineering (BSME) degree program at Virginia Tech is accredited by the Engineering Accreditation Commission of ABET, www.abet.org (http://www.abet.org), under the commission's General Criteria and the Program Criteria for Mechanical and Similarly Named Engineering Programs.

Program Educational Objectives

Within a few years after graduating from the Mechanical Engineering Department at Virginia Tech, the graduates will attain:

- Positions where they utilize fundamental technical knowledge and skills in mathematics, science, and engineering to analyze and solve problems, and apply these abilities to generate new knowledge, ideas or products in academia, industry or government.
- Practical experience and organizational skills, enabling them to interact and communicate effectively (written and/or oral) with others (e.g., supervisor, client and/or team) with regard to the diversity of the stakeholders involved in their work.
- Roles of increasing responsibility leading to leadership positions that benefit themselves, their employers and society.
- Skills in life-long learning through: (a) self-study, (b) continuing education/short courses or workshops, and/or (c) formal graduate level education, as well as skills to motivate and encourage co-workers to also pursue lifelong learning.
- Roles in professional and personal life where they demonstrate professional and ethical responsibilities toward peers, employers, and society and follow these precepts in their daily lives.

Student Learning Outcomes

We expect our students to have the following skills, knowledge, and behaviors by the time of their graduation. We want our students to obtain:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The Curriculum

The department is committed to providing students with an exceptional experience in both the theory and practice of mechanical engineering. In the senior capstone sequence students are required to apply classroom knowledge to complex engineering problems requiring teamwork, problem formulation, economic analysis, effective communication, and product realization. These projects are carefully selected and updated to ensure relevancy to contemporary technical issues and needs. The department encourages the involvement of students prior to their senior year and students outside the department and college in these projects. The department also encourages hands-on student involvement by providing dedicated machine and welding shops that exclusively serve the undergraduate program. The required sophomore-level Manufacturing Processes Laboratory course and certification by a professional machinist are required prior to use of either of these shops. Opportunity for professional development is provided by participation in student professional organizations, such as the American Society

of Mechanical Engineers, ASME, and the American Nuclear Society, ANS. In addition to the *Mechanical Engineering* major, there are majors in *Automotive Engineering* and *Robotics and Mechatronics* which offer additional specialization in those areas while still leading to the BS in Mechanical Engineering degree.

The ME curriculum provides a strong foundation in the basic physical and chemical sciences and in mathematics. These are followed by courses that provide a background in thermodynamics, numerical methods, solid and fluid mechanics, manufacturing processes, machine design, vibrations, heat and mass transfer, controls, statistics and materials. Courses in English and in the humanities and social sciences are included to broaden the individual. This background is strengthened and unified through a sequence of engineering design courses. Instructional laboratories in the junior year provide opportunities for students to learn measurement and instrumentation techniques. Students apply these skills to the acquisition and analysis of data from various engineering systems.

In all professional endeavors the mechanical engineer must consider ecological effects as well as the economic and social needs of people. The mechanical engineer must consider the conservation of natural resources and the environmental impact in the design of systems. These considerations are included in a number of ME courses and technical elective classes. Students wishing to further strengthen this area may wish to consider the Green Engineering Option at www.eng.vt.edu/green/index.php (http://www.eng.vt.edu/green/).

The unifying activity in all aspects of mechanical engineering is the design function. A special emphasis has been placed on the use of computer-aided design methods and applied design project experience as a required part of the curriculum. Elective courses in the junior and senior years provide students with the opportunity to pursue specialized interests related to career plans or preparation for graduate study.

The department participates in the Cooperative Education Program in which qualified students may alternate semesters of study with semesters of professional employment. Approximately twenty percent of all mechanical engineering students participate in this program.

The department offers graduate programs leading to the M.S., M.Eng., and Ph.D. in mechanical engineering (see the Graduate Catalog (https://catalog.vt.edu/graduate/)).

The Department of Mechanical Engineering actively seeks input on the nature and quality of our program from all interested individuals and organizations, including students, employers and supporting agencies. Our goal is to provide the best possible service to the students who entrust their education to us. Through our continuous improvement efforts, we pledge to continually improve the content of our curriculum, our educational methods and our facilities. Comments to the department head or any member of the faculty are welcomed. Note that because of this continuous improvement process entrance and degree requirements and course content are subject to change. Please consult the department academic advisor for current information.

- Automotive Engineering Major (https://catalog.vt.edu/undergraduate/college-engineering/mechanical-engineering/automotive-engineering-bs/)
- Mechanical Engineering Major (https://catalog.vt.edu/undergraduate/college-engineering/mechanical-engineering/mechanical-engineering-bs/)
- Robotics and Mechatronics Major (https://catalog.vt.edu/undergraduate/college-engineering/mechanical-engineering/robotics-mechatronics-bs/)

Head: B. Lattimer
William S. Cross Professor: D. K. Tafti
Nicholas & Rebecca Des Champs Professor: B. Lattimer
George R. Goodson Professor: R. Pitchumani
Lewis A. Hester Professor: R. L. Mahajan
Robert E. Hord Jr. Professor: C. Sandu
Robert E. Hord Jr. Professor: M. von Spakovsky
Samuel P. Langley Professor: C.R. Fuller
W. Martin Johnson Professor: A.J. Kurdila
Chris C. Kraft Professor of Engineering: W. F. Ng
Clifton C. Garvin Professor: R.C. Batra
J. Bernard Jones Professor: M. Ahmadian
John R. Jones III Fellow: B. Behkam
John R. Jones III Fellow: J. Boreyko
John R. Jones III Fellow: R. Mirzaeifar
John R. Jones III Fellow: R. Qiao
Mary V. Jones Fellow: L. Li
Rolls Royce Professor: C. Son
L. S. Randolph Professor: C.B. Williams
University Distinguished Professor: R.C. Batra
Adhesive and Sealant Science Professor: D.A. Dillard
Professors: M. Ahmadian, R.C. Batra, B. Behkam, P. Ben-Tzvi, L. Collins, R. De Vita, D.A. Dillard, A. Eskandarian, C.R. Fuller, A. Haghighat, A.J. Kurdila, B. Lattimer, A. Leonessa, R.L. Mahajan, R. Mueller, D.J. Nelson, W.F. Ng, M.R. Paul, R. Pitchumani, R. Qiao, C. Sandu, J.J. Socha, C. Son, M.A. Stremler, D.K. Tafti, S. Taheri, M.R. von Spakovsky, C.B. Williams, and J. Zhang
Associate Professors: P. Acar, A. Asbeck, O. Barry, J.H. Bohn, J. Boreyko, J. Cheng, M.W. Ellis, J.B. Ferris, W. Hardy, C. Hin, S. Huxtable, M.E.F. Kasarda, K.B. Kochersberger, S. Li, Z. Li, Y. Liu, R. Mirzaeifar, A.S. Nain, B. Raeymaekers, S. Shahab, S.C. Southward, A.E. Staples, A. Untaroiu, R.L. West, and A.L. Wicks
Assistant Professors: K.H. Akbari, M. Bartlett, S. Kale, E. Komendera, L. Li, D. Losey, J. Meadows, J. Palmore, Z. Tian
Assistant Professor of Practice: R. Long
Associate Professor of Practice: R. Ott and L. Vick
Collegiate Associate Professor: D. Gonzales, J.K. Lord, M. Nowinski, and J. Warfford
Professors Emeritus: L.J. Arp, R.A. Comparin, N.S. Eiss, R.E. Hedgepeth, C.J. Hurst, , R.G. Leonard, J. R. Mahan, L.D. Mitchell, R. Mitchiner, A. Myklebust, T.F. Parkinson, F.J. Pierce, J.R. Thomas, W.C. Thomas, and R.J. Whitelaw
Adjunct Professors: R. Anderl (TU Darmstadt), P.G. Brolinson (Edward Via College of Osteopathic Medicine), D. Carlson (Lord Corp.), J. Funk (Biodynamic Research Corp.), M.J. Hampe (TU Darmstadt), T. Kress (BEST Engineering), D. Rabe (Air Force Research Lab), and B. Sanders (Air Force Research Lab)
Advanced Instructors: B. Aidi, J. Bolton, C. Galitz, S. Davison, S. Tahmasian
Instructors: J. Barbish, T.S. Chang, R. Clark, H. Pendar, J. Rule

Undergraduate Course Descriptions (ESM)

ESM 2014 - Professnl Dvlpmnt Seminar ESM (1 credit)
Topics designed to foster the professional development of the ESM student. ESM program objectives and outcomes. Professional careers, employment opportunities, expectations to the profession. Technical concentration within the ESM major. Ethical decision-making, safe and life-long learning.
Instructional Contact Hours: (1 Lec, 1 Crd)

ESM 2104 - Statics (3 credits)
Vector mechanics of forces and moments, free-body diagrams, couples, resultants, equilibrium of particles and rigid bodies in two and three dimensions, forces in trusses, frames, and machines, centroids, centers of mass, distributed forces, internal shear forces and bending moments in beams, shear and moment diagrams, friction, belt friction, area of moments of inertia, parallel axis theorem. Course requirements may be satisfied by taking MATH prerequisite prior to or concurrent with course.
Prerequisite(s): MATH 1226
Corequisite(s): MATH 2204 or MATH 2204H or MATH 2406H
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 2114 - Statics & Structures (3 credits)
Vector algebra of forces, movements, couples and resultants. Free-body diagrams. Equilibrium of particles and rigid bodies in two and three dimensions. Friction. Forces in trusses and frames. Centroids, centers of mass, area moments of inertia. Internal axial forces, shear forces, and bending moments in bars in beams. Shear and moment diagrams. Stress and strain in bars in beams.
Corequisite(s): MATH 2204 or MATH 2204H or MATH 2406H.
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 2204 - Mechanics of Deformable Bodies (3 credits)
Concepts of stress, strain, and deformation. Factor of safety. Stress-strain relationships and material properties. Stress concentrations. Area moments of inertia. Axially loaded members, torsionally loaded members, bending of beams. Shear and moment diagrams. Stresses due to combined loading. Thin-walled pressure vessels. Transformation of stress including Mohrs circle. Beam deflections and buckling stability.
Prerequisite(s): (ESM 2104 or ESM 2114) and (MATH 2204 or MATH 2204H or MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 2304 - Dynamics (3 credits)
Vector treatment of the kinematics and kinetics of particles and rigid bodies, Newtons laws, work and energy, impulse and momentum, impact, mass moments of inertia, rotating axes.
Prerequisite(s): (ESM 2104 or ESM 2114) and (MATH 2204 or MATH 2204H or MATH 2406H)
Corequisite(s): MATH 2214
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 2974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 2984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 2994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 2994H - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 3024 - Introduction to Fluid Mechanics (3 credits)
Fluid properties. Hydrostatics. Derivation and application of the mass, momentum, and energy conservation equations. Dimensional analysis and similitude. Introduction to analyses of pipe flows and piping systems, open channel flows, and fluid forces on solid bodies.
Prerequisite(s): PHYS 2305 and ESM 2104
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3034 - Fluid Mechanics Laboratory (1 credit)
Introduction to experimental fluid mechanics. Dimensional analysis. Experiments on fluid properties, flow measurements, and flow visualization, including manometry, determining hydrostatic forces on submerged surfaces, applications of the impulse-momentum principle, velocity measurements, measuring drag forces, quantifying flow in channels. Modern data acquisition techniques.
Prerequisite(s): ESM 2304 and ECE 3054
Corequisite(s): ESM 3234
Instructional Contact Hours: (3 Lab, 1 Crd)

ESM 3054 - Mechanical Behavior of Materials (3 credits)
Mechanical properties and behavior of solid materials subjected to static, cyclic, and sustained loads resulting from stress states, environments, and stress histories typical of service conditions; multiaxial failure criteria; behavior of cracked bodies; fatigue of materials; creep of materials; microstructure-property relationships; design methodologies.
Prerequisite(s): ESM 2204 and (MSE 2034 or MSE 2044 or MSE 3094 or AOE 3094 or CEE 3684)
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: MSE 3054

ESM 3064 - Mechanical Behavior of Materials Laboratory (1 credit)
Laboratory experiments on behavior and mechanical properties of solid materials. Tension, compression, bending, hardness, nano-indentation, and impact tests; behavior of cracked bodies; fatigue and crack growth tests; creep deformation; microstructure-property relationships; laboratory equipment, instrumentation, and computers.
Prerequisite(s): ESM 2204
Corequisite(s): ESM 3054
Instructional Contact Hours: (3 Lab, 1 Crd)
Course Crosslist: MSE 3064

ESM 3114 - Problem Definition and Scoping in Engineering Design (1 credit)
Define open-ended engineering design projects, identify relevant broad social, global, economic, cultural and technical needs and constraints, determine ways in which technical skills contribute to addressing complex engineering design challenges. Identify a capstone project for ESM 4015-4016. Pre-requisite: Junior standing in ESM.
Prerequisite(s): ESM 2014
Instructional Contact Hours: (2 Lab, 1 Crd)

ESM 3124 - Dynamics II- Analytical and 3-D Motion (3 credits)
Review of Newtons Laws, introduction to Lagranges equations, rotating coordinate systems, particle dynamics, systems of particles, rigid-body dynamics, small amplitude oscillations, holonomic and nonholonomic constraints, phase space and energy methods.
Prerequisite(s): ESM 2304 and (MATH 2214 or MATH 2214H or MATH 2406H) and (MATH 2204 or MATH 2204H or MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3134 - Dynamics III - Vibration and Control (3 credits)
Single-degree-of-freedom vibration, n-degree-of-freedom systems, continuous systems, nonlinear systems, system stability, introduction to the feedback control of dynamic systems.
Prerequisite(s): ESM 3124 and MATH 4564
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3154 - Solid Mechanics (3 credits)
Introduction to tensors, mathematical description of deformations and internal forces in solids, equations of equilibrium, principle of virtual work, linear elastic material behavior, solution for linear elastic problems including axially and spherically symmetric solutions, stress function solutions to plane stress and strain problems, solutions to 3-D problems, energy methods.
Prerequisite(s): ESM 2204 and (MATH 2214 or MATH 2214H)
Corequisite(s): MATH 4574
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3234 - Fluid Mechanics I-Control Volume Analysis (3 credits)
Fluid statics. Control volume approach to flow analysis: conservation laws, pipe flows, compressible flow, open channel flow.
Prerequisite(s): ESM 2304 and PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3334 - Fluid Mechanics II-Differential Analysis (3 credits)
Introduction to continuum mechanics for fluid systems. Fluid kinematics. Differential approach to flow analysis: conservation equations, exact solutions, potential flows, viscous flows.
Prerequisite(s): ESM 3234 or ME 3404
Corequisite(s): MATH 4574
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 3444 - Mechanics Laboratory (2 credits)
Concepts in instrumentation, data acquisition, and signal analysis. Measurements of mechanics quantities and phenomena associated with solid, fluid, and dynamical systems. Open-ended problem definition and approach formulation. Application and synthesis of engineering mechanics fundamentals to the modeling and solution of open-ended problems. Group-working skills and effective written and oral communication.
Prerequisite(s): ESM 3234 and ESM 3034 and ESM 3054 and ESM 3064 and ESM 3124 and ECE 3054
Corequisite(s): ESM 3134, ESM 3154, ESM 3334
Instructional Contact Hours: (1 Lec, 3 Lab, 2 Crd)

ESM 3704 - Basic Principles of Structures (3 credits)
Static equilibrium of forces and moments, concurrent and nonconcurrent force systems, center of gravity, concentrated and distributed loads. Solution of trusses. Stress and strain, elastic behavior of materials, cables and arches, shear, bending, and deformation in beams, indeterminate structures. Not available to students in engineering.
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4014 - Applied Fluid Mechanics (3 credits)
Analysis of flow over practical configurations, panel methods, Reynolds-averaged Navier-Stokes equations, turbulent boundary layers, flow separation and three-dimensional effects. Unsteady flows, fluid-structure interactions.
Prerequisite(s): ESM 2074 and ESM 3016
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4015 - Creative Design and Project (3 credits)
Capstone senior design project. Synthesis and application of fundamental principles of engineering science and mechanics to an open-ended problem. 4015: Project proposal, including objectives, goals and plans for project. Identification of needs, constraints, and engineering standards with consideration of public health, safety, and welfare, including ethical, global, cultural, societal, environmental, and economic contexts. Proof-of-concept prototyping. Teamwork and communication of design and project progress. 4016: Design specifications with consideration of public health, safety, and welfare, as well as ethical, global, cultural, social, environmental, and economic factors where applicable. Design, test, and analysis of functional prototype. Teamwork and communication of design and project progress. Pre: Senior standing.
Prerequisite(s): ESM 3114
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4016 - Creative Design and Project (3 credits)
Capstone senior design project. Synthesis and application of fundamental principles of engineering science and mechanics to an open-ended problem. 4015: Project proposal, including objectives, goals and plans for project. Identification of needs, constraints, and engineering standards with consideration of public health, safety, and welfare, including ethical, global, cultural, societal, environmental, and economic contexts. Proof-of-concept prototyping. Teamwork and communication of design and project progress. 4016: Design specifications with consideration of public health, safety, and welfare, as well as ethical, global, cultural, social, environmental, and economic factors where applicable. Design, test, and analysis of functional prototype. Teamwork and communication of design and project progress. Pre: Senior standing.
Prerequisite(s): ESM 4015
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4024 - Advanced Mechanical Behavior of Materials (3 credits)
Mechanical behavior of materials, emphasizing solid mechanics aspects and methods for predicting strength and life of engineering components. Plasticity, failure criteria, fracture mechanics, crack growth, strain-based fatigue, and creep. Microstructure-property relationships, and laboratory demonstrations.
Prerequisite(s): ESM 3054 or MSE 3054
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4044 - Mechanics of Composite Materials (3 credits)
Introduction to the deformation, stress, and strength analysis of continuous-fiber-polymer-matrix laminated composites. Fabrication, micromechanics of stiffness and expansional coefficients, classical lamination theory (CLT). Environmentally induced stresses. Computerized implementation and design.
Prerequisite(s): ESM 2204 or AOE 2024
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CEE 4610

ESM 4084 - Engineering Design Optimization (3 credits)
Use of mathematical programming methods for engineering design optimization including linear programming, penalty function methods, and gradient projection methods. Applications to minimum weight design, open-loop optimum control, machine design, and appropriate design problems from other engineering disciplines.
Prerequisite(s): MATH 2224 or MATH 2204 or MATH 2204H
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4084

ESM 4105 - Engineering Analysis of Physiologic Systems (3 credits)
Engineering analysis of human physiology. Physiologic systems are treated as engineering systems with emphasis input-output considerations, system interrelationships and engineering analogs. 4105 - Mass and electrolyte transfer, nerves, muscles, renal system. 4106 - cardiovascular mechanics, respiratory system, digestive systems, senses.
Prerequisite(s): ESM 2304 and MATH 2214
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4106 - Engineering Analysis of Physiologic Systems (3 credits)
Engineering analysis of human physiology. Physiologic systems are treated as engineering systems with emphasis input-output considerations, system interrelationships and engineering analogs. 4105 - Mass and electrolyte transfer, nerves, muscles, renal system. 4106 - cardiovascular mechanics, respiratory system, digestive systems, senses.
Corequisite(s): ME 3105
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4114 - Nonlinear Dynamics and Chaos (3 credits)
Motion of systems governed by differential equations: stability, geometry, phase planes, bifurcations, Poincare sections, point attractors, limit cycles, chaos and strange attractors, Lyapunov exponents. Forced, nonlinear oscillations: jump phenomena, harmonic resonances, Hopf bifurcations, averaging and multiple-scales analysis. Systems governed by discrete maps: return maps, cobweb plots, period-multiplying bifurcations, intermittency, delay coordinates, fractal dimensions.
Prerequisite(s): (ESM 2304 or PHYS 2504) and (MATH 2214 or MATH 2214H)
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4514

ESM 4154 - Nondestructive Evaluation of Materials (3 credits)
Concepts and methods of nondestructive evaluation of materials. Discussion of techniques and mathematical bases for methods involving mechanical, optical, thermal, and electromagnetic phenomena; design for inspectability; technique selection criteria; information processing and handling; materials response measurement and modeling; signal analysis.
Prerequisite(s): ESM 3054 and (PHYS 2206 or PHYS 2306)
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4194 - Sustainable Energy Solutions for a Global Society (3 credits)
Addresses energy metrics, global and US energy supply and demand, transitional energy sources (natural gas, petroleum, coal, nuclear), sustainable/renewable source (solar, geothermal, hydro, tidal, wind, biofuels), and methods for increasing efficiencies (energy storage, batteries, green building, conservation). Options for transportation, electricity, lighting and heating needs of industry, agriculture, community, and citizens. Production, transmission, storage, and disposal issues considered in the context of global political, economic, and environmental impacts. Senior Standing in major may be substituted for pre-requisite ENGL 3764.
Prerequisite(s): (CHEM 1035 or CHEM 1055) and PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: ME 4194

ESM 4204 - Musculoskeletal Biomechanics (3 credits)
Skeletal anatomy and mechanics. Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research.
Prerequisite(s): ESM 2304 and (CS 1044 or CS 1064 or CS 1114 or AOE 2074 or ESM 2074 or ME 2004)
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4224 - Biodynamics and Control (3 credits)
Study of human movement dynamics and neuromuscular control of multi-degree-of-freedom systems. Computational simulation of forward-dynamics and state-space linear control of human movement to investigate functional performance and neuromuscular pathology.
Prerequisite(s): ESM 2304
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4234 - Mechanics of Biological Systems (3 credits)
Anatomy and physiology of biological systems such as cells, tissues, and organs. Experimental techniques for determining the mechanical behavior of biological systems. Simplified mechanics-based mathematical models of biological systems. Specific biological systems include cells, tissues, and organs of the musculoskeletal, cardiovascular, integumentary system, and reproductive systems.
Prerequisite(s): ESM 2204 and MATH 2214 and MATH 2114
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: BMES 4234

ESM 4245 - Mechanics of Animal Locomotion (3 credits)
4245: Mechanical and biological principles of terrestrial animal locomotion, including walking, running, jumping, climbing, burrowing, and crawling. Terrestrial locomotion- based bio-inspired design. 4246: Mechanical and biological principles of animal locomotion in fluids, including active and gliding flight, swimming, jetting, and running on water. Engineering design inspired by fluid based biological locomotion.
Prerequisite(s): ESM 3054
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4246 - Mechanics of Animal Locomotion (3 credits)
Mechanical and biological principles of of animal locomotion in fluids, including active and gliding flight, swimming, jetting, and running on water. Enginneering desgn inspired by fluid-based biological locomotion.
Prerequisite(s): ESM 3234 or ME 3414
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4304 - Hemodynamics (3 credits)
Study of the human cardiovascular system and blood flow. Anatomy and physiology of the human heart, vascular system, and its organization. Blood physiology and rheology. Non-Newtonian blood flow models. Steady and pulsatile blood flow in rigid and elastic arteries. Pressure waves in elastic arteries. Three-dimensional blood flow in the aortic arch and flow around heart valves.
Prerequisite(s): ESM 3334 or ME 3404 or ME 3414
Instructional Contact Hours: (3 Lec, 3 Crd)

ESM 4404 - Fundamentals of Professional Engineering (2 credits)
A refresher of basic principles and problem solving techniques involving twelve subject areas most common to all engineering curricula. The topics include those tested by the National Council of Engineering Examiners on the EIT (Engineer in Training) examination, the first requirement, in all fifty states, toward P.E. (Professional Engineer) licensing. Duplicates material of other engineering courses and impracticable for non-engineers, hence not usable for credit toward any degree. Pre: Junior and senior standing in Engineering or in Building Construction or Graduate students in Engineering.
Instructional Contact Hours: (2 Lec, 2 Crd)

ESM 4444 - Stability of Structures (3 credits)
Introduction to the methods of static structural stability analysis and their applications. Buckling of columns and frames. Energy method and approximate solutions. Elastic and inelastic behavior. Torsional and lateral buckling. Use of stability as a structural design criterion.
Prerequisite(s): AOE 3024 or CEE 3404
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4054

ESM 4614 - Probability-Based Modeling, Analysis, and Assessment (3 credits)
Uncertainty analysis of engineering data, parameters estimation, probability concepts, random variables, functions of random variables, probability-based performance functions and failure modes, risk and reliability functions, probability of failure and safety index, random sequences and stochastic processes, correlation functions and spectral densities, return period and extreme values, failure rates, performance monitoring and service life prediction.
Prerequisite(s): ESM 2204
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: BMES 4614

ESM 4734 - An Introduction to the Finite Element Method (3 credits)
The finite element method is introduced as a numerical method of solving the ordinary and partial differential equations arising in fluid flow, heat transfer, and solid and structural mechanics. The classes of problems considered include those described by the second-order and fourth-order ordinary differential equations and second-order partial differential equations. Both theory and applications of the method to problems in various fields of engineering and applied sciences will be studied.
Prerequisite(s): (CS 3414 or MATH 3414 or AOE 2074 or ESM 2074) and (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4024

ESM 4904 - Project and Report (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 4974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 4974H - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 4984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 4994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ESM 4994H - Undergraduate Research (1-19 credits)
Honors
Instructional Contact Hours: Variable credit course

Undergraduate Course Descriptions (ME)

ME 2004 - Engineering Analysis Using Numerical Methods (3 credits)
Numerical methods applied to engineering analysis with a design/lab studio. Numerical techniques including root finding, linear algebra, integration, ordinary differential equations, curve fitting, discrete Fourier transforms, optimization. Structured programming and iterative problem-solving using a high-level environment such as Matlab. Design/Lab Studio.
Prerequisite(s): (ENGE 1215 or ENGE 1414) and MATH 1226 and (MATH 2114 or MATH 2114H or MATH 2405H or MATH 2214 or MATH 2214H or MATH 2406H)
Instructional Contact Hours: (2 Lec, 2 Lab, 3 Crd)

ME 2024 - Introduction to Engineering Design and Economics (3 credits)
Design process, mini-design projects, collaborative design, product dissection, economics of decision making, reverse engineering, intellectual property, oral, written, and graphic communications, engineering ethics.
Prerequisite(s): ENGE 1216 or ENGE 1114 or ENGE 1434 or ENGE 1414
Corequisite(s): ESM 2104, MATH 2114, PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 2124 - Introduction to Thermal and Fluid Engineering (2 credits)
Basics of thermodynamics, fluid mechanics, and heat transfer. Fluid and thermal properties of materials. Ideal gas equation of state. First law of thermodynamics in closed systems. Transient heat transfer. First law of thermodynamics in open systems. Fluid mechanics balances, open systems. Emphasis on applications in all topic areas.
Prerequisite(s): (ESM 2104 or PHYS 2306) and (MATH 2114 or MATH 2114H)
Corequisite(s): MATH 2214
Instructional Contact Hours: (2 Lec, 2 Crd)

ME 2134 - Thermodynamics (4 credits)
Classical (equilibrium) thermodynamics and its applications. Includes thermodynamic properties of pure substances: property diagrams, property tables, property software, equations of state; the first law of thermodynamics; the second law of thermodynamics; gas mixtures; combustion: atomic and energy balances; and power and refrigeration cycles.
Prerequisite(s): PHYS 2305 and (MATH 2204 or MATH 2204H or MATH 2406H) and CHEM 1035
Corequisite(s): (MATH 2214 or MATH 2214H or MATH 2406H).
Instructional Contact Hours: (4 Lec, 4 Crd)

ME 2974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 2974H - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 2984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 2994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 2994H - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 3024 - Engineering Design and Economics (3 credits)
Engineering design process; project management; product planning; customer needs, specifications, and Quality Function Deployment (QFD); benchmarking and intellectual property; concept generation, screening, scoring, and selection; design for assembly, product architecture, economic, and ethical considerations; concept testing. Written and oral communications of engineering design; computer aided design. Team-based term project with prototype fabrication of mechanical assembly manipulated by a microcontroller. For Pathways Advanced Discourse credit, must complete combination of ME 3024, ME 3034, and ME 4015-4016.
Prerequisite(s): ESM 2104 and ENGL 1106
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3034 - Mechanical Engineering Discourse (1 credit)
Principles and application of effective technical and professional communication in mechanical engineering; organizing, structuring, and developing effective written documents and oral presentations for a range of audiences, including technical reports, memorandums, laboratory reports, live and recorded presentations, and posters for public exhibition; use of effective language and style; development of effective visual aids; presentation delivery skills; acquiring new knowledge using appropriate learning strategies by finding, comprehending and evaluating information from a variety of sources; ethical and professional responsibilities in both identifying appropriate information and communicating technical results. For Pathways Advanced Discourse credit, must complete combination of ME 3024, ME 3034, and ME 4015-4016.
Prerequisite(s): ENGL 1106
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (1 Lec, 1 Crd)

ME 3124 - Thermodynamics (3 credits)
Classical thermodynamics and its applications. Thermodynamic properties of pure substances: property tables, property software, equations of state. First law of thermodynamics. Second law of thermodynamics. Gas mixtures. Combustion: atom and energy balances. Power and refrigeration cycles.
Prerequisite(s): (ME 2124 and MATH 2214 and MATH 2204) or (ME 2124 and MATH 2214 and MATH 2204H) or (ME 2124 and MATH 2214 and MATH 2224) or (ME 2124 and MATH 2214 and MATH 2224H) or (ME 2124 and MATH 2214H and MATH 2204) or (ME 2124 and MATH 2214H and MATH 2204H) or (ME 2124 and MATH 2214H and MATH 2224) or (ME 2124 and MATH 2214H and MATH 2224H) or (ME 2124 and MATH 2405H and MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3134 - Fundamentals of Thermodynamics (3 credits)
Fundamental concepts, first and second laws, gas and vapor processes with emphasis on chemical reactions, statistical interpretation of entropy, limited use of thermodynamic property tables. This course is for non-ME students.
Prerequisite(s): MATH 2214 or MATH 2214H
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3194 - Technology, Innovation and Humanistic Engineering for a Sustainable Future (3 credits)
Foundational understanding of converging, emerging and disruptive technologies. Pedagogical aspects of innovation, team dynamics and effective communication. Leadership Cube—Six principles of effective leadership. Humanistic engineering. Sustainable energy and sustainable water platforms. Smart device designs for disease diagnostics and mitigation. Pre: Junior standing.
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3304 - Heat and Mass Transfer (3 credits)
Comprehensive basic course in heat and mass transfer for mechanical engineering students. Principles of conduction, convection, and radiation with applications to heat exchangers and other engineering systems.
Prerequisite(s): ME 2134 and ME 3414 and (MATH 2214 or MATH 2214H or MATH 2306H) and (MATH 2204 or MATH 2204H or MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3404 - Fluid Mechanics (3 credits)
Comprehensive first course in basic and applied fluid mechanics. Fluid properties, statics, kinematics, and dynamics. Eulers and Bernoullis equations. Hydrodynamics. Dimensional analysis and similitude. Real fluids, laminar and turbulent flows. Boundary layer model and approximate analysis. Compressible flow and propulsion devices. Flow measurement. Introduction to turbomachinery with applications.
Prerequisite(s): (ME 2124 and MATH 2214 and MATH 2204) or (ME 2124 and MATH 2214 and MATH 2204H) or (ME 2124 and MATH 2214 and MATH 2224) or (ME 2124 and MATH 2214 and MATH 2224H) or (ME 2124 and MATH 2214H and MATH 2204) or (ME 2124 and MATH 2214H and MATH 2204H) or (ME 2124 and MATH 2214H and MATH 2224) or (ME 2124 and MATH 2214H and MATH 2224H) or (ME 2124 and MATH 2405H and MATH 2406H)
Instructional Contact Hours: (2 Lec, 1 Lab, 3 Crd)

ME 3414 - Fluid Dynamics (4 credits)
Comprehensive first course in fluid dynamics. Fluid properties. Hydrostatics. Mass, momentum,and energy conservation in control volumes. Elementary dynamics and Bernoullis equation.Dimensional analysis and similitude. Laminar and turbulent flows. Introduction to Eulers and Navier-Stokes equations. Pipe flows. External flows and boundary layers. Introduction to compressible flows. Includes laboratory experiments.
Prerequisite(s): ME 2004 and (MATH 2114 or MATH 2114H or MATH 2405H) and (MATH 2204 or MATH 2204H or MATH 2406H) and (MATH 2214 or MATH 2214H or MATH 2406H)
Corequisite(s): ME 2134
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ME 3504 - Dynamic Systems - Vibrations (3 credits)
Principles of dynamic system modeling with emphasis on second order mechanical systems. Harmonic and nonharmonic vibrations of single and multi-degree of freedom systems. Applications of computer simulation and analysis techniques in vibrations.
Prerequisite(s): (ME 3514 and MATH 2214) or (ME 3514 and MATH 2214H) or (ME 3514 and MATH 2405H and MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3514 - System Dynamics (3 credits)
Mathematical descriptions of physical systems behavior including mechanical, electrical, thermal, and fluid systems and their combinations; system descriptions using state variable and transfer functions; analysis of system responses: convolution integral, frequency response, numerical simulations, and Laplace transform methods; systems concepts: input-output, causality, and analogies; general process descriptions including first-order, second-order, and time delayed.
Prerequisite(s): (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204 and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204 and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204 and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204H and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204H and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2204H and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224 and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224 and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224 and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224H and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224H and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214 and MATH 2224H and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204 and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204 and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204 and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204H and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204H and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2204H and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224 and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224 and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224 and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224H and MATH 2114) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224H and MATH 2114H) or (ESM 2104 and ESM 2304 and MATH 2214H and MATH 2224H and MATH 2405H) or (ESM 2104 and ESM 2304 and MATH 2405H and MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3524 - Mechanical Vibrations (4 credits)
Development and application of mathematical methods, physical understanding, and computational tools for modeling, analysis, and design of vibrating systems. Free and forced vibration of single and multiple degree-of-freedom systems, particularly systems experiencing sinusoidal excitation. Distributed parameter systems. Practical engineering applications.
Prerequisite(s): ESM 2304 and (MATH 2114 or MATH 2114H or MATH 2405H) and (MATH 2214 or MATH 2214H or MATH 2406H) and ME 2004
Instructional Contact Hours: (4 Lec, 4 Crd)

ME 3534 - Controls Engineering I (4 credits)
Fundamentals of feedback control theory, time-domain and frequency-domain analysis, automatic control system design synthesis to meet performance and stability requirements, numerical simulation and discrete real-time implementation on microcontrollers.
Prerequisite(s): ME 2004 and (MATH 2114 or MATH 2114H or MATH 2405H) and (MATH 2214 or MATH 2214H or MATH 2406H) and (MATH 2204 or MATH 2204H or MATH 2406H) and ESM 2104 and ESM 2304
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ME 3604 - Kinematics and Dynamics of Machinery (3 credits)
Kinematic analysis and design of cams, gears, and linkages, velocity, acceleration and force analysis, kinematic synthesis, balancing, kinematic and force analysis by complex numbers, computer-aided analysis, and synthesis of linkages.
Prerequisite(s): ESM 2304
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3614 - Mechanical Design I (3 credits)
Design of mechanical components subject to static and fatigue loads. Design using screws, fasteners, springs and bearings. Computer-aided design using transfer matrix and finite element methods.
Prerequisite(s): ESM 2204 and (MATH 2214 or MATH 2214H) and (MATH 2114 or MATH 2114H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 3624 - Mechanical Design (4 credits)
Comprehensive first course in mechanical design. Stress and Strain. Fundamentals of designing mechanical components subjected to static and cyclical loads. Design elements for screws, fasteners, springs, and welds. Hands-on laboratory learning of concepts discussed in class. Course credit will not be awarded for both ME 3614 and ME 3624.
Prerequisite(s): ME 2004 and ESM 2204 and (MATH 2214 or MATH 2214H or MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Lab, 4 Crd)

ME 3984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 4005 - Mechanical Engineering Lab (3 credits)
Principles of measurement, measurement standards and accuracy, detectors and transducers, digital data acquisition principles, signal conditioning systems and readout devices statistical concepts in measurement, experimental investigation of engineering systems, technical report writing.
Prerequisite(s): (STAT 3704 or STAT 4604 or STAT 4705 or STAT 4714) and ME 3524 and ECE 2054
Corequisite(s): ME 3534
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)

ME 4006 - Mechanical Engineering Lab (3 credits)
Principles of measurement, measurement standards and accuracy, detectors and transducers, digital data acquisition principles, signal conditioning systems and readout devices statistical concepts in measurement, experimental investigation of engineering systems, technical report writing.
Prerequisite(s): ME 4005 and ECE 3254
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)

ME 4015 - Engineering Design and Project (3 credits)
Team oriented, open-ended, multi-disciplinary design projects focused on industrially relevant problems. A specific, complex engineering design problem taken from problem definition to product realization and testing. Emphasis on documenting and reporting technical work. Making informed judgments which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. 4015: Problem identification, including consideration of public health and welfare, as well as global, cultural, social, environmental, and economic factors and constraints; idea generation and concept selection; application of design, test, and analysis tools developed in previous courses; ethical and professional responsibilities; verification and validation; communication and working in teams. 4016: Project management; working on teams, analysis and optimization, fabrication and testing, and communicating technical ideas. For Pathways Advanced Discourse credit, must complete combination of ME 3024, ME 3034, and ME 4015-4016.
Prerequisite(s): ME 3024 and ME 3034 and ME 3524 and ME 3534 and ME 3624 and ME 4005 and (ME 3304 or MSE 2034) and ME 3414
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)

ME 4016 - Engineering Design and Project (3 credits)
Team oriented, open-ended, multi-disciplinary design projects focused on industrially relevant problems. A specific, complex engineering design problem taken from problem definition to product realization and testing. Emphasis on documenting and reporting technical work. Making informed judgments which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. 4015: Problem identification, including consideration of public health and welfare, as well as global, cultural, social, environmental, and economic factors and constraints; idea generation and concept selection; application of design, test, and analysis tools developed in previous courses; ethical and professional responsibilities; verification and validation; communication and working in teams. 4016: Project management; working on teams, analysis and optimization, fabrication and testing, and communicating technical ideas. For Pathways Advanced Discourse credit, must complete combination of ME 3024, ME 3034, and ME 4015-4016.
Prerequisite(s): ME 4015
Pathway Concept Area(s): 1A Discourse Advanced, 10 Ethical Reasoning
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)

ME 4034 - Bio-Inspired Technology (3 credits)
Introduction to engineering solutions inspired by biological systems. Overview over the approach of bio-inspired technology and the state of the art. Exploration of the relationship between engineered and natural biological systems. Explanation of concepts of biological systems, such as evolutionary optimization, sensing, actuation, control, system integration, assembly and materials in engineering terms. Practice of interdisciplinary analysis skills in technical report writing projects where man-made and biological systems are evaluated for parallels to engineering and their technological potential.
Prerequisite(s): (PHYS 2205 and PHYS 2206) or (PHYS 2305 and PHYS 2306)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4124 - Computer Aided Design of Fluid-Thermal Systems (3 credits)
Review of physical laws and engineering concepts introduced in thermodynamics, fluid mechanics, and heat transfer with applications. Emphasis on analysis, modeling, and design of engineering systems, components, and physical phenomena with state-of-the-art computer software such as Ansys CFX, Star CCM, Aspen Plus, and ProSimPlus.
Prerequisite(s): (ME 3124 or ME 2134) and (ME 3404 or ME 3414) and ME 3304
Instructional Contact Hours: (2 Lec, 2 Lab, 3 Crd)

ME 4154 - Industrial Energy Systems (3 credits)
Survey of energy-intensive technologies used in typical industrial plants, with emphasis on cost-effective energy conservation. Burners, boilers, pumps, air compressors, electric motors, lights, refrigeration plants, HVAC systems, cogeneration systems, waste heat recovery equipment. Energy-efficient design and operation. Determination of energy efficiency based on field measurements. Economic analysis of energy conservation measures. Mitigation of environmental impacts.
Prerequisite(s): ME 2134 or CHE 2164 or BSE 3154
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4164 - Energy Systems for Buildings (3 credits)
Application of the fundamental principles of thermodynamics, heat transfer, and fluid flow to analyze energy use for building environmental control. Exploration of approaches for configuring basic thermal-fluid engineering components (e.g. pumps, piping, fans, heat exchangers, refrigeration cycles, etc.) to yield systems that provide heating, cooling, and ventilation. Introduction to techniques and software tools for estimating energy use by these systems and the associated economic and environment impact. Examination of alternate technologies for meeting building energy needs including small scale combined heat and power systems and renewable energy systems.
Prerequisite(s): ME 2134
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4174 - Spacecraft Propulsion (3 credits)
Spacecraft propulsion systems and their applications in orbital, interplanetary, and interstellar flight. Rocket propulsion fundamentals; advanced mission analysis; physics and engineering of chemical rockets, electrical thrusters, and propellantless systems (tethers and sails); spacecraft integration issues.
Prerequisite(s): AOE 3164 or AOE 4234 or ME 4234
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4174

ME 4184 - Drone Technology and Flight Operations (3 credits)
Basic aviation science, skills training in uncrewed flight operations, and knowledge of the regulatory environment that governs drone flight. Aerodynamics, propulsion, aircraft performance, sensing and control, meteorology, the Federal Aviation Regulations, safety and risk management. Flight management tools for conducting preflight inspections and approving flight missions. Pre: Students in Mechanical Engineering will be given preference, other programs and students eligible with permission.
Instructional Contact Hours: (2 Lec, 1 Lab, 3 Crd)

ME 4194 - Sustainable Energy Solutions for a Global Society (3 credits)
Addresses energy metrics, global and US energy supply and demand, transitional energy sources (natural gas, petroleum, coal, nuclear), sustainable/renewable source (solar, geothermal, hydro, tidal, wind, biofuels), and methods for increasing efficiencies (energy storage, batteries, green building, conservation). Options for transportation, electricity, lighting and heating needs of industry, agriculture, community, and citizens. Production, transmission, storage, and disposal issues considered in the context of global political, economic, and environmental impacts. Senior Standing in major may be substituted for pre-requisite ENGL 3764.
Prerequisite(s): (CHEM 1035 or CHEM 1055) and PHYS 2306
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: ESM 4194

ME 4204 - Internal Combustion Engines (3 credits)
Analysis and design of gasoline and diesel engines. Fundamental processes and their application in current technology. Thermodynamics: air standard and air-fuel cycles. Combustion: stoichiometry, fuels, chemical equilibrium, chemical kinetics, flame propagation, knock, pollutant formation and control. Flow processes: volumetric efficiency, intake and exhaust tuning, two-stroke scavenging, carburetion, fuel injection, super- and turbo-charging.
Prerequisite(s): ME 2134 and ME 3414
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4224 - Gas Turbines for Power and Propulsion (3 credits)
Introduction to various applications of gas turbines for land, sea and air. Aero-thermo-mechanical aspects of component performance and reliability. Operational characteristics, limitations and component matching. Industrial standards, development and certification requirements. Design of gas turbine engines and comparison of the predicted performance (specific fuel consumption) against the in-service operation.
Prerequisite(s): ME 2134 and ME 3414
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4234 - Aerospace Propulsion Systems (3 credits)
Design principles and performance analysis of atmospheric and space propulsion engines and systems. Application of thermodynamics, compressible fluid flow and combustion fundamentals to the design of gas turbine and rocket engines and components, including inlets, turbomachines, combustors, and nozzles. Matching of propulsion system to vehicle requirements. Must have a C- or better in pre-requisites ME 3404 and ME 3124 or AOE 3114 and AOE 3134.
Prerequisite(s): AOE 3114 and (AOE 3164 or AOE 3264) or ME 3414 and ME 2134
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: AOE 4234

ME 4324 - Energy Systems: Theory and Applications (3 credits)
Theory and applications of thermodynamic and fluid mechanics principles as applied to energy systems. Fundamental concepts on exergy, mixtures, psychrometry and thermochemistry. Analyses and applications include vapor and gas power systems, refrigeration, air conditioning, combustion processes and one-dimensional compressible flow.
Prerequisite(s): ME 2134 and ME 3414
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4344 - Biological Transport Phenomena (3 credits)
Engineering analysis and predictive modeling of heat and mass transport in biological systems (e.g., tissues, organs, organisms, and biomedical devices). Examination of processes that involve conduction, convection, diffusion, generation/consumption. Application of analytical and computational methods to solve differential equations that describe unsteady and/or multi-dimensional transport. Topics include oxygen transport, pharmacokinetic analysis, kidney function, blood perfusion, burns, and cryopreservation.
Prerequisite(s): (CHE 3114 and CHE 3044 and CHE 3144) or (ME 3304 and ME 3404)
Instructional Contact Hours: (3 Lec, 3 Crd)
Course Crosslist: CHE 4304

ME 4454 - Engineering Leadership in Practice: Managing the Technical Design Process (3 credits)
Introduction to management and mentoring skills associated with the application of the engineering design process. Course covers skills necessary for leading diverse teams of people through a technical design project. Managing teams of local high school students through an authentic technical design experience associated with design competitions. Course addresses the practical applications of science, math and engineering, while building and managing teams of people to meet technical project goals. Prerequisite: ME 4015 or similar team-based design experience, or by permission of instructor.
Prerequisite(s): ME 4015
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)
Course Crosslist: EDCI 4454

ME 4504 - Dynamic Systems - Controls Engineering I (3 credits)
Fundamentals of feedback control theory, classical analysis and design techniques for automatic controls, introduction to modern control theory.
Prerequisite(s): (ME 3514 and MATH 2214) or (ME 3514 and MATH 2214H) or (ME 3514 and MATH 2405H and MATH 2406H)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4524 - Introduction to Robotics and Automation (3 credits)
Automation, robot technology, kinematics, dynamics, trajectory planning, and control of two-dimensional and spatial robots; robot programming; design and simulation of robotic devices.
Prerequisite(s): ME 2004 and ME 3524 and ME 3534
Corequisite(s): ME 4584
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4534 - Land Vehicle Dynamics (3 credits)
Analytical methods for land vehicle dynamics. Mechanics of pneumatic tires on pavement and steel wheels on rails. Vehicle stability, handling, response to random guideway and roadway irregularities, ride quality computation methods and standards, suspension design.
Prerequisite(s): ME 3524
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4544 - Automotive Engineering (3 credits)
Vehicle performance, drive train, suspension, steering, and brake systems. Steady state and transient conditions. Senior standing in Mechanical Engineering required.
Prerequisite(s): ME 3524
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4554 - Advanced Technology for Motor Vehicles (3 credits)
Energy use and environmental issues for motor vehicles: Emissions standards, fleet requirements, dynamometer testing, fuel economy, and vehicle performance. Alternative fuel vehicles: Characteristics and infrastructure of fuels, batteries, electric vehicles, and hybrid electric vehicles. Vehicle design: Modeling and simulation of vehicle energy use and performance, component sizing. Fuel cells for transportation. Heavy-duty vehicles and busses. Low mass vehicles and future vehicle technology.
Prerequisite(s): ME 2134
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4564 - Vehicle Control (3 credits)
Overview of vehicle control systems and control algorithms for anti-lock braking, stability, road holding, lane departure, traction control, and tire pressure monitoring. Advanced driver assist systems and intelligent tire technology. Hands-on experience with hardware-in-the- loop systems. Mathematical modeling and simulation of vehicle control.
Prerequisite(s): ME 3524 and ME 3534
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4584 - Robotics Laboratory (1 credit)
Develop, compile, and test algorithms for serial and mobile robots. Robot forward and inverse kinematics, task planning, velocity kinematics, force rendering, control, haptics, mapping and localization, computer vision and path planning.
Corequisite(s): ME 4524 or ECE 4704
Instructional Contact Hours: (3 Lab, 1 Crd)
Course Crosslist: ECE 4584

ME 4614 - Mechanical Design II (3 credits)
Design of mechanical elements such as welded joints hydrodynamic bearings, spur gears, shafts, brakes. Alternative fatigue design methods, cumulative fatigue, mechanical design computer software.
Prerequisite(s): ME 3624
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4624 - Finite Element Practice in Mechanical Design (3 credits)
Application of the finite element method to stress analysis problems in mechanical design. Modeling techniques, proper use of existing computer programs, interpreting of results, application to design modification.
Prerequisite(s): ME 3624
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4634 - Introduction to Computer-aided Design and Manufacturing (3 credits)
Participants will study the computer-aided design and manufacturing of mechanical systems. A mechanical system will be designed including preliminary design, analysis, detail design, numerical control programming, and documentation. Applications programs will be written and interfaced to the CAD/CAM database. All assignments will be carried out on a CAD/CAM system.
Prerequisite(s): ME 3024
Instructional Contact Hours: (2 Lec, 3 Lab, 3 Crd)

ME 4644 - Introduction to Rapid Prototyping (3 credits)
Participants will study topics fundamental to rapid prototyping and automated fabrication, including the generation of suitable CAD models, current rapid prototyping fabrication technologies, their underlying material science, the use of secondary processing, and the impact of these technologies on society. The rapid prototyping process will be illustrated by the actual design and fabrication of a part. Programming skills required.
Prerequisite(s): ME 3024
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4654 - Optimization Techniques in Engineering (3 credits)
Fundamental mathematical concepts for optimization and optimality conditions. Classification of optimization techniques/problems in engineering. Concepts of forward and inverse design. Linear programming. Step-size calculation methods. Search direction calculation methods. 1st and 2nd order gradient-based algorithms. Evolutionary strategies for optimization. Pattern search/genetic algorithm. Sensitivity analysis. Reliability-based and robustness-based optimization.
Prerequisite(s): ME 2004 or (AOE 2074 and CS 1044 and CS 1054 and CS 1064 and CS 1114 and CS 1124 and ECE 1574)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4664 - Introduction to Global Collegiate Engineering Design (3 credits)
Participants will study topics fundamental to global collaborative engineering design, product data management, and collaborative product data management. These topics will be applied during a team project with team members located overseas, utilizing state-of-the-art collaborative engineering and product data management software and hardware technologies. Partially duplicates 5664. Credit may only be received for one course.
Prerequisite(s): ME 3024
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4674 - Materials Selection in Mechanical Design (3 credits)
Systematic approach to materials selection accounting for market need, functional requirements, shape, safety, cost and environmental issues. Overview of design process, material property charts, material indices, selection of materials with multiple constraints and/or conflicting objectives, shape factors, design considerations in hybrid materials, environmental issues as well as several case studies.
Prerequisite(s): ESM 2204 and MSE 2034
Corequisite(s): ME 3624
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4684 - Industrial Internet of Things (3 credits)
Theory and applications of Industrial Internet of Things (IIoT). Industrial data flow, devices and network in manufacturing. Basics for IIoT architecture and implementation of IIoT solutions with cloud computing platforms and OEM IIoT platforms. Device connection, data transfer and application of diagnostics, maintenance, and predictive data analytics on IIoT platforms.
Prerequisite(s): ME 3534 or (CS 1044 or CS 1054 or CS 1064 or CS 1114)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4724 - Engineering Acoustics (3 credits)
Basic acoustical theory and practice, acoustic terminology, measurement, transmission, and perception of sound, muffler design, noise control techniques.
Prerequisite(s): ME 3524
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4734 - Robotics and Mechatronics Seminar (1 credit)
Topics in robotics and mechatronics. Invited lectures from industry, government organizations and universities. Recent research results, developments and challenges, providing a global and social context for the topics.
Prerequisite(s): ME 3534 and ECE 3254
Instructional Contact Hours: (1 Lec, 1 Crd)

ME 4735 - Mechatronics (3 credits)
Electromechanical system modeling, control and applications. Design and building of electronic interfaces and controllers for mechanical devices, sensors, signal acquisition, filtering, and conditioning. Microcontroller-based closed-loop control and device communications. Sensor and actuator selection, installation, and application strategies are studied. A term design project is a key component to this course (for 4736).
Prerequisite(s): (ECE 3254 and ME 3514) or (ECE 2004 and ECE 2704)
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4736 - Mechatronics (3 credits)
Electromechanical system modeling, control and applications. Design and building of electronic interfaces and controllers for mechanical devices, sensors, signal acquisition, filtering, and conditioning. Microcontroller-based closed-loop control and device communications. Sensor and actuator selection, installation, and application strategies are studied. A term design project is a key component to this course (for 4736).
Prerequisite(s): ME 4735
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4744 - Mechatronics: Theory and Application (4 credits)
Electromechanical design and control applications. Theory, modeling, simulation, analysis, design and building of electronic interfaces and controllers; sensors and actuators; software development, micro-controller technology, and applications. Design Lab/Studio.
Prerequisite(s): ME 3534 and ECE 3254 and (CS 1044 or ECE 1574 or CS 2505)
Instructional Contact Hours: (3 Lec, 2 Lab, 4 Crd)

ME 4754 - Mechatronics: Advanced Topics and Application (3 credits)
Electromechanical design and control applications. Design and building of electronic interfaces and controllers including sensors, actuators, signal acquisition, filtering, and conditioning for applications. Systems integration with wireless communication; image processing; embedded programs for data acquisition and feedback control applications.
Prerequisite(s): ME 4744
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4764 - Audio Engineering Technology (3 credits)
Principles and design in the field of audio engineering. Loudspeaker design and construction, microphone technology, digital audio acquisition, signal processing in audio engineering, human perception, technical acoustics, binaural hearing, surround sound processing and production, theory, measurement, and reproduction of 3D surround sound, virtual instrument theory and practice, room acoustics and simulation, principles of audio effects (e.g., compression, reverberation, equalization), and acoustic materials engineering.
Prerequisite(s): ME 3524 and ME 3534
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4824 - Introduction to Human-Robot Interaction (3 credits)
Formalizing interaction between robots and humans. Developing learning and control algorithms that enable robots to seamlessly and intelligently collaborate with humans. Mathematical approaches to human-robot interaction, learning from demonstration, Bayesian inference, intent detection, safe and optimal control, assistive autonomy, and user study design. Review and present existing literature.
Prerequisite(s): ME 4524
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4854 - Nano and Micromechanics of Materials (3 credits)
Analysis of microstructural mechanics, crystal structures, defects, and dislocations. Mechanical behavior of crystalline materials at the microscale. Computational modeling of mechanical behavior in discrete atomistic and molecular systems, including molecular dynamics. Application of these methods to polymers and other soft materials, biological materials, carbon-based materials, and metallic alloys.
Prerequisite(s): ESM 2204
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4864 - Micro/Nano-Robotics (3 credits)
Overview of Micro/Nano-robotic systems. Physics of reduced length scales (scaling effects in the physical parameters, surface forces, contact mechanics, and Micro/Nano-scale dynamical phenomena), Basics of Micro/Nano-manufacturing, microfabrication and soft lithography, Biomimetic design strategies for mobile micro-robots, Principle of transduction, material properties and characteristics of Micro/Nano-actuators (piezoelectric, shape-memory alloy, and a variety of MEMS and polymer actuators), Control requirements and challenges of Micro/Nano-actuators, Micro/Nano sensors for mobile microrobotic applications, Micro/Nano-manipulation (scanning probe microscopy, operation principles, designing experiments for nanoscale mechanical characterization of desired samples).
Prerequisite(s): ME 3414 and ME 3624 and ME 3534
Instructional Contact Hours: (3 Lec, 3 Crd)

ME 4974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 4974H - Independent Study (1-19 credits)
Honors
Instructional Contact Hours: Variable credit course

ME 4984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 4984A - Special Study (1-19 credits)
Pathway Concept Area(s): 1A Discourse Advanced
Instructional Contact Hours: Variable credit course

ME 4994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

ME 4994H - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

Undergraduate Course Descriptions (NSEG)

NSEG 3145 - Fundamentals of Nuclear Engr (3 credits)
Application of fundamental principles of neutron physics and reactor theory. Introduction to nuclear cross-section data, neutron scattering, nuclear fission, and diffusion theory. Examination of current and next generation nuclear power.
Prerequisite(s): MATH 2214 or MATH 2214H or MATH 2406H
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 3146 - Fundamental of Nuclear Engr (3 credits)
Application of fundamental principles of neutron physics and reactor theory. Calculation of critical mass and dimensions of a reactor using modified one-group theory; reactivity changes in the core due to control rods, chemical boron shim, temperature changes, and fissioin production poisons. Determination of reactor thermal design criteria. Introduction to radiation protection and reactor accident analysis. Nuclear enginering ethics principles.
Prerequisite(s): NSEG 3145 or ME 3145
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 3604 - Radiation Detection, Protection and Shielding (3 credits)
Radioactive decay, interaction of charged particles and photons with matter, methods of radiation detection and radiation dosimetry, counting statistics, radiation protection criteria and exposure limits, external radiation protection using time, distance and shielding.
Prerequisite(s): PHYS 2306
Corequisite(s): MATH 2214 or MATH 2214H or MATH 2406H.
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 4204 - Nuclear Fuel Cycle (3 credits)
Uranium nuclear fuel cycle: radiation basics, uranium reserves, mining, conversion, enrichment, fuel manufacturing, in-core fuel management and refueling, spent fuel storage, reprocessing/recycling and final disposition as waste in a geologic repository. Introduction to nuclear safeguards and nonproliferation as applied to each step of cycle. Alternative fuel cycles.
Prerequisite(s): MATH 2214
Corequisite(s): NSEG 3146
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 4214 - Nuclear Power Plant Operations (3 credits)
Emphasis on pressurized water reactor plant operations. Review of boiling water reactor operations. Detailed system functions and operation, reactor plant startup and shutdown procedures, reactor refueling, reactor plant safety analysis, reactor plant licensing, ethics and integrity in the nuclear industry.
Prerequisite(s): NSEG 3145
Corequisite(s): NSEG 3146
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 4424 - Reactor Thermal Hydraulics (3 credits)
Fundamental processes of heat generation and transport in nuclear reactors: reactor coolant systems and components, heat generation and spatial distribution, heat transport by conduction and convection, single-phase flow, two-phase flow and boiling, critical heat flux.
Prerequisite(s): MATH 2214
Corequisite(s): NSEG 3145
Instructional Contact Hours: (3 Lec, 3 Crd)

NSEG 4974 - Independent Study (1-19 credits)
Instructional Contact Hours: Variable credit course

NSEG 4984 - Special Study (1-19 credits)
Instructional Contact Hours: Variable credit course

NSEG 4994 - Undergraduate Research (1-19 credits)
Instructional Contact Hours: Variable credit course

NSEG 4994H - Undergraduate Research (1-19 credits)
Honors Section
Instructional Contact Hours: Variable credit course