MECHANICAL & AEROSPACE ENGINEERING (EMAE)

EMAE 160. Mechanical Manufacturing. 3 Units.
The course is taught in two sections-Graphics and Manufacturing. Manufacturing To introduce manufacturing processes and materials and their relationships to mechanical design engineering. Course includes hands-on machining and metal fabrication lab. Also, each lab creates a 'virtual' field trip of a manufacturing facility to be shared with the class. Graphics Development of mechanical engineering drawings in orthographic, sectional, and pictorial views using manual drafting and computer-aided drafting (CAD software), dimensioning, tolerancing geometric dimensioning and tolerancing and assembly drawings will also be covered. All students are paired up to give a Manufacturing Design Presentation demonstrating the course material. The course has two (75) minute lectures and one (110) minute Machining Lab per week.

EMAE 181. Dynamics. 3 Units.
Elements of classical dynamics: particle kinematics and dynamics, including concepts of force, mass, acceleration, work, energy, impulse, momentum. Kinetics of systems of particles and of rigid bodies, including concepts of mass center, momentum, mass moment of inertia, dynamic equilibrium. Elementary vibrations. Recommended preparation: MATH 122 and PHYS 121 and ENGR 200.

EMAE 250. Computers in Mechanical Engineering. 3 Units.
Numerical methods including analysis and control of error and its propagation, solutions of systems of linear algebraic equations, solutions of nonlinear algebraic equations, curve fitting, interpolation, and numerical integration and differentiation. Recommended preparation: (ENGR 130 or ENGR 131) and MATH 122.

EMAE 251. Thermodynamics. 3 Units.
Thermodynamic concepts and definitions, properties of pure substances, work and heat, first and second laws, entropy, power and refrigeration cycles, thermodynamic relations, mixtures and solutions, chemical reactions, phase and chemical equilibrium. Prereq: CHEM 111, PHYS 121 and MATH 122.

EMAE 252. Fluid Mechanics. 3 Units.
Fluid properties, hydrostatics, fluid dynamics and kinematics, control volume analysis, differential analysis, dimensional analysis and similitude, viscous internal flows, external flows and boundary layers, lift and drag. Prereq: EMAE 251 and MATH 223.

EMAE 260. Design and Manufacturing I. 3 Units.
This is the second course of a 4-course sequence focusing on "Engineering Design and Manufacturing." This course develops students' competence and self-confidence as design engineers by exposing the students to design as a creative process and its relationship with modern manufacturing practices. The outcomes of the course focus on the student's ability to apply their knowledge of mathematics, science, and engineering to design a system, component, or process that meets desired needs within realistic, multi-dimensional constraints, such as: economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. Additionally, students will be given the opportunity to identify, formulate, and solve engineering problems, while applying professional and ethical practices. Professional communication skills are emphasized and expected during all stages of the design process. The course has five main areas of emphasis: design as a creative process, decision-based design methodologies, project management, engineering economics, and design for manufacture (CAD/CAM/CAE) using industrial software tools. The course exposes the student to the integration of engineering design, manufacturing, and management disciplines and includes activities to consider and understand the complex processes associated with controlling and managing product data through all stages of the product life-cycle (PLM). Topics include: engineering ethics, design as a creative process, design methodologies, project management, engineering economics, product life-cycle management (PLM), CAD/CAE/CAM, and the role of digital manufacturing within the design process. Design/Rapid Prototyping Studio activities are an integral part of the course, and enable the students to be part of a design and build team working on various project-based tasks. Prereq: EMAE 160.

EMAE 272. Actuators and Drive Trains. 3 Units.
Graphical, analytical, and computer techniques for analyzing displacements, velocities, and accelerations in mechanisms. Analysis and synthesis of linkages, cams, and gears. Analysis of actuators, including motors, linear actuators, solenoids, hydraulics, pneumatics,and piezoelectrics. Laboratory projects include analysis, design, construction, and evaluation of students' devices that include both actuators and transmission mechanisms. Prereq: EMAE 181 and EMAE 250.

EMAE 285. Mechanical Engineering Measurements Laboratory. 4 Units.
Techniques and devices used for experimental work in mechanical and aerospace engineering. Lecture topics include elementary statistics, linear regression, propagation of uncertainty, digital data acquisition, characteristics of common measurement systems, background for measurement laboratories, and elements of report writing. Hands-on laboratory experiences may include measurements in solid mechanics, dynamics, and fluid and thermal sciences, which are summarized in lab reports. At least one report will focus on design of a measurement. Recommended preparation: EMAE 181, EMAE 251, EMAE 252 and ECIV 310. Counts as a Disciplinary Communication course.

EMAE 290. Computer-Aided Manufacturing. 3 Units.
An advanced design and manufacturing engineering course covering a wide range of topics associated with the 'design for manufacturability' concept. Students will be introduced to a number of advanced solid modeling assignments (CAD), rapid prototyping (RP), and computer-aided manufacturing (CAM). In addition students will be introduced to computer numerical control (CNC) manual part-programming for CNC milling and turning machine tools. All students will be given a design project requiring all detail and assembly drawings for a fully engineered design. The course has two (50) minute lectures and one (110) minute CAD/CAM Lab per week. Prereq: EMAE 160.

EMAE 307. Fundamentals of Biomechanics. 3 Units.
Fundamentals of biomechanics will teach students how to apply basic principles of mechanics to understand, explain and model biological processes at across the relevant length-scales (cell-tissue-organ-organism), and over a broad range of physiological systems (respiratory, ocular, circulatory, and musculoskeletal). Physiology of organs and tissues that are involved in biomechanical functions will also be covered. Offered as EMAE 307 and EBME 317. Prereq: ENGR 200.

EMAE 350. Mechanical Engineering Analysis. 3 Units.
Methods of problem formulation and application of frequently used mathematical methods in mechanical engineering. Modeling of discrete and continuous systems, solutions of single and multi-degree of freedom problems, boundary value problems, transform techniques, approximation techniques. Recommended preparation: MATH 224.

EMAE 351. Control of Mechanical Systems. 3 Units.
An introduction to automatic control theory with emphasis on mechanical and electromechanical systems. Review of Laplace Transforms, mathematical modeling of mechanical systems, state variable models, feedback control characteristics and performance, stability analysis; root locus techniques; Bode plots and Nyquist diagrams for stability analysis in frequency domain; transient and steady-state response and design of closed loop control systems. Prereq: EMAE 181, EMAE 252, EMAE 350, and ENGR 210.

EMAE 353. Heat Transfer. 3 Units.
Steady-state and transient conduction, principles of convection, empirical relations for forced convection, natural convection, boiling and condensation, radiation heat transfer, heat exchangers, mass transfer. Prereq: EMAE 251 and EMAE 252.

EMAE 355. Design of Fluid and Thermal Elements. 3 Units.
Synthesis of fluid mechanics, thermodynamics, and heat transfer. Practical design problems originating from industrial experience. Recommended preparation: EMAE 251, EMAE 252, and EMAE 353.

EMAE 356. Aerospace Design. 3 Units.
Interactive and interdisciplinary activities in areas of fluid mechanics, heat transfer, solid mechanics, thermodynamics, and systems analysis approach in design of aerospace vehicles. Projects involve developing (or improving) design of aerospace vehicles of current interest (aircraft and spacecraft) starting from mission requirements to researching developments in relevant areas and using them to obtain conceptual design. Prereq: EMAE 160, EMAE 355, EMAE 376, EMAE 383, EMAE 384 and Senior standing. Coreq: EMAE 382.

EMAE 359. Aero/Gas Dynamics. 3 Units.
Review of conservation equations. Potential flow. Subsonic airfoil. Finite wing. Isentropic one-dimensional flow. Normal and oblique shock waves. Prandtl-Meyer expansion wave. Supersonic airfoil theory. Prereq: EMAE 252.

EMAE 360. Design and Manufacturing II. 3 Units.
This is the third course of a 4-course sequence focusing on "Engineering Design and Manufacturing," and is the senior capstone design course focused on a semester-long design/build/evaluate project. The course draws on a student's past and present academic and industrial experiences and exposes them to the design and manufacture of a product or device that solves an open-ended "real world" problem with multidimensional constraints. The course is structured and time-tabled within the Case School of Engineering (CSE) to give the EMAE 360 students the opportunity to team with students from other CSE departments to form multidisciplinary design teams to work on the solution to a common problem. The outcomes of the course continue to focus on the student's ability to function on multidisciplinary teams while applying their knowledge of mathematics, science and engineering to design a system, component, or process that meets desired needs within realistic, multidimensional constraints, such as: economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. Professional communication skills are emphasized and expected during all stages of the design process and will include formal and informal oral presentations, periodic peer-focused design reviews, and a development through its various evolutionary stages to completion. Counts as a SAGES Senior Capstone course. Prereq: EMAE 160 and EMAE 260.

EMAE 370. Design of Mechanical Elements. 3 Units.
Application of mechanics and mechanics of solids in machine design situations. Design of production machinery and consumer products considering fatigue and mechanical behavior. Selection and sizing of basic mechanical components: fasteners, springs, bearings, gears, fluid power elements. Prereq: ECIV 310 and ENGR 200.

EMAE 371. Computational Fluid Dynamics. 3 Units.
Finite difference, finite element, and spectral techniques for numerical solutions of partial differential equations. Explicit and implicit methods for elliptic, parabolic, hyperbolic, and mixed equations. Unsteady incompressible flow equations in primitive and vorticity/stream function formulations. Steady and unsteady transport (passive scalar) equations. Offered as EMAE 371 and EMAE 471.

EMAE 372. Structural Materials by Design. 4 Units.
Materials selection and design of mechanical and structural elements with respect to static failure, elastic stability, residual stresses, stress concentrations, impact, fatigue, creep, and environmental conditions. Mechanical behavior of engineering materials (metals, polymers, ceramics, composites). Influence of ultrastructural and microstructural aspects of materials on mechanical properties. Mechanical test methods covered. Models of deformation behavior of isotropic and anisotropic materials. Methods to analyze static and fatigue fracture properties. Rational approaches to materials selection for new and existing designs of structures. Failure analysis methods and examples, and the professional ethical responsibility of the engineer. Four mandatory laboratories, with reports. Offered as EMAE 372 and EMSE 372. Prereq or Coreq: ENGR 200.

EMAE 373. Dynamics of Machinery. 3 Units.
Dynamics of interacting machine component, comprehensive understanding of system dynamic behavior. Kinetics of 3-dimensionl rigid bodies. Mathematical formulations of multi-degree-of-freedom mechanisms. Balancing of reciprocating and rotating machinery. Fluid-film and rolling contact bearings. Time-dependent gear mesh stiffness. Prereq: EMAE 181 and EMAE 272 and EMAE 370.

EMAE 376. Aerostructures. 3 Units.
Mechanics of thin-walled aerospace structures. Load analysis. Shear flow due to shear and twisting loads in open and closed cross-sections. Thin-walled pressure vessels. Virtual work and energy principles. Introduction to structural vibrations and finite element methods. Recommended preparation: ECIV 310.

EMAE 377. Biorobotics Team Research. 3 Units.
Many exciting research opportunities cross disciplinary lines. To participate in such projects, researchers must operate in multi-disciplinary teams. The Biorobotics Team Research course offers a unique capstone opportunity for undergraduate students to utilize skills they developed during their undergraduate experience while acquiring new teaming skills. A group of eight students form a research team under the direction of two faculty leaders. Team members are chosen from appropriate majors through interviews with the faculty. They will research a biological mechanism or principle and develop a robotic device that captures the actions of that mechanism. Although each student will cooperate on the team, they each have a specific role, and must develop a final paper that describes the research generated on their aspect of the project. Students meet for one class period per week and two 2-hour lab periods. Initially students brainstorm ideas and identify the project to be pursued. They then acquire biological data and generate robotic designs. Both are further developed during team meetings and reports. Final oral reports and a demonstration of the robotic device occur in week 15. Offered as EMAE 377 and EMAE 477. Counts as a SAGES Senior Capstone course.

EMAE 379. Mechanics and Control of Compliant Robotics. 3 Units.
Robots are fundamentally mechanical devices designed to function autonomously or semi-autonomously. In autonomous systems including animals and robots, one of the most important mechanical properties is stiffness. Selective compliance allows robots to grasp a wide range of objects and traverse rougher terrain. A new field of Soft Robotics aims to create robots that are robust, cheap, and safe in close proximity to humans. However, as engineers challenge themselves to make increasingly soft robots, new challenges in design and control need to be addressed. This course will provide an introduction to state of the art in robotics as cyber-physical systems from a fundamental mechanics perspective. Topics include: grasping, wearable assistive locomotion, legged locomotion, locomotion in fluids, and locomotion over soft terrain. Offered as EMAE 379 and EMAE 479. Prereq: (ENGR 130 or ENGR 131 or CSDS 132 or ECSE 132) and EMAE 181 and ECSE 304.

EMAE 382. Propulsion. 3 Units.
Energy sources of propulsion. Performance criteria. Review of one-dimensional gas dynamics. Airbreathing engine cycle analysis and turbomachinery. Introduction of thermochemistry and combustion. Rocket flight performance and rocket staging. Chemical liquid and solid rockets. Offered as EMAE 382 and EMAE 482. Prereq: EMAE 251 and EMAE 359.

EMAE 383. Flight Mechanics. 3 Units.
Aircraft performance: take-off and landing, unaccelerated flight, range and endurance, flight trajectories. Aerodynamics and propulsion. Aircraft static stability and control, simple maneuvers. Aircraft flight dynamics and control, flight simulation. Offered as EMAE 383 and EMAE 483. Prereq: EMAE 181 and EMAE 252 and EMAE 359 and (EECS 304 or ECSE 304).

EMAE 384. Orbital Dynamics. 3 Units.
Spacecraft orbital mechanics: the solar system, elements of celestial mechanics, orbit transfer under impulsive thrust, continuous thrust, orbit transfer, decay of orbits due to drag, elements of lift-off and re-entry. Rigid body dynamics, altitude dynamics and control, simulations. Prereq: EMAE 181 and EMAE 252 and EMAE 359 and (EECS 304 or ECSE 304).

EMAE 387. Vibration Problems in Engineering. 4 Units.
Free and forced vibration problems in single and multi-degree of freedom damped and undamped linear systems. Vibration isolation and absorbers. Modal analysis and approximate solutions. Introduction to vibration of continuous media. Noise problems. Laboratory projects to illustrate theoretical concepts and applications. Recommended preparation: MATH 224 and EMAE 181.

EMAE 390. Advanced Manufacturing Technology. 3 Units.
This course will focus on advanced manufacturing technologies and processes, with an emphasis on the fundamental understanding of the material behaviors and process in the manufacturing operations. Topics will include: materials in manufacturing, glass manufacturing, polymer composite manufacturing, metal casting, metal machining, metal forming, grinding, welding, heat treatment, and quality control. The course will be lecture-based, with lab-based class project in the machine shop and think[box] studios. Prereq: EMAE 290.

EMAE 397. Independent Laboratory Research. 1 - 3 Units.
Independent research in a laboratory.

EMAE 398. Senior Project. 3 Units.
Individual or team design or experimental project under faculty supervisor. Requirements include periodic reporting of progress, plus a final oral presentation and written report. Recommended preparation: Senior standing, EMAE 360, and consent of instructor. Counts as a SAGES Senior Capstone course.

EMAE 399. Advanced Independent Laboratory Research/Design. 1 - 3 Units.
Students perform advanced independent research or an extended design project under the direct mentorship of the instructor. Typically performed as an extension to EMAE 397 or EMAE 398. Prereq: EMAE 397.

EMAE 400S. Graduate Seminar I. 0 Unit.
This course will expose the Ph.D. candidate to research in the fields of Mechanical and Aerospace Engineering in the form of seminars given by invited speakers, faculty candidates, and other graduate students and postdocs within the department. The student must attend a minimum of 8 seminars during the semester to earn a Pass, which can be any combination of departmental seminars, special invited seminars (including faculty candidates), and/or the student seminar series. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 400T. Graduate Teaching I. 0 Unit.
This course will engage the Ph.D. candidate in a variety of teaching experiences that will include direct contact (for example, teaching recitations and laboratories, guest lectures, office hours) as well non-contact preparation (exams, quizzes, demonstrations) and grading activities. The teaching experiences will be conducted under the supervision of the faculty member(s) responsible for coordinating student teaching activities. All Ph.D. candidates enrolled in this course sequence will be expected to perform direct contact teaching at some point in the sequence. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 401. Mechanics of Continuous Media. 3 Units.
Vector and tensor calculus. Stress and traction, finite strain and deformation tensors. Kinematics of continuous media, general conservation and balance laws. Material symmetry groups and observer transformation. Constitutive relations with applications to solid and fluid mechanics problems.

EMAE 414. Nanobiomechanics in Biology. 3 Units.
This course will elucidate the forces at play at the level of proteins including those associated with mass, stiffness, viscosity, thermal and chemical factors. Basic polymer mechanics within the context of biological molecules will be covered and structures of key proteins associated with mechanical functions, such as actin, myosin and the cell membrane will be explained. Generation of force by polymerization of filamentous proteins as well as motor proteins will be included. Interaction forces between proteins, DNA/RNA mechanics will also be elucidated. Besides lectures, there will be term long project assignments (outreach-based or detailed literature survey on a subject associated with nanomechanics of cells/proteins). Recommended Preparation: Mechanics of Materials, Thermodynamics, Statics, Introductory Level Differential Equations, Introductory Level Fluid Mechanics.

EMAE 415. Introduction to Musculo-skeletal Biomechanics. 3 Units.
Structural behavior of the musculo-skeletal system. Function of joints, joint loading, and lubrication. Stress-strain properties of bone and connective tissue. Analysis of fracture and repair mechanisms. Viscoplastic modeling of skeletal membranes. Recommended preparation: EMAE 181 and ECIV 310.

EMAE 450. Advanced Mechanical Engineering Analysis. 3 Units.
This course is intended to equip students with tools for solving mathematical problems commonly encountered in mechanical, fluid and thermal systems. Specific goals are to: i) Enable the student to properly categorize the problem in a variety of ways ii) Enable the student to identify appropriate approaches to solving the problem ii) Provide the student experience in applying some common methods for obtaining numerical solutions iii) Provide the student with understanding of trade-offs and expectations for the methods used. The course covers topics related to analytical and computational approaches to problems categorized in a variety of ways including: 1. Linear versus nonlinear problems 2) finite degrees of freedom v. infinite degrees of freedom, 3) equilibrium v. propagation v. eigenvalue problems, 4) direct formulations v. indirect formulations 5) analytical v. numerical solutions. The course will be built around specific examples from solid mechanics, dynamics, vibrations, heat transfer and fluid mechanics. The significance of the various categorizations will be developed as an ongoing part of the approach to solving the problems. Prereq: EMAE 350 or Requisites Not Met permission.

EMAE 453. Advanced Fluid Dynamics I. 3 Units.
Derivation and discussion of the general equations for conservation of mass, momentum, and energy using tensors. Several exact solutions of the incompressible Newtonian viscous equations. Kinematics and dynamics of inviscid, incompressible flow including free streamline theory developed using vector, complex variable, and numerical techniques.

EMAE 454. Advanced Fluid Dynamics II. 3 Units.
Continuation of EMAE 453. Low Reynolds number approximations. Matching techniques: inner and outer expressions. High Reynolds number approximations: boundary layer theory. Elements of gas dynamics: quasi one-dimensional flow, shock waves, supersonic expansion, potential equation, linearized theory, and similarity rules. Recommended preparation: EMAE 453.

EMAE 455. Advanced Thermodynamics. 3 Units.
Basic ideas of thermodynamics and dominant methods of their development: operational, postulational, and statistical. Entropy and information theory. Irreversible thermodynamics. Applications.

EMAE 456. Micro-Electro-Mechanical Systems in Biology and Medicine (BioMEMS). 3 Units.
Microscale technologies have enabled advanced capabilities for researchers in unexplored territories of cells in biology and medicine. Biological (or Biomedical) Micro-Electro-Mechanical Systems (MEMS) and Biomanufacturing involve the fundamentals of mechanics, electronics and advanced microfabrication technologies with specific emphasis on biological applications. MEMS is an interdisciplinary research area which brings together multiple disciplines including, mechanical engineering, biomedical engineering, chemical engineering, materials science, electrical engineering, clinical sciences, medicine, and biology. MEMS based technologies have found real world applications in tissue engineering, implantable microdevices, proteomics, genomics, molecular biology, biosensing, and point-of-care diagnostic platforms. This course aims to: (1) introduce the need for miniaturized systems in biology and medicine and the fundamental design and microfabrication concepts, (2) introduce the basics of microscale manipulation of cells, biological agents, and biomanufacturing, employing the fundamentals of microscale behaviors of fluids and mechanical systems, (3) expose the students to applications of MEMS, biosensing, and on-chip technologies in biology and medicine. Offered as EBME 456 and EMAE 456.

EMAE 457. Combustion. 3 Units.
Chemical kinetics and thermodynamics; governing conservation equations for chemically reacting flows; laminar premixed and diffusion flames; turbulent flames; ignition; extinction and flame stabilization; detonation; liquid droplet and solid particle combustion; flame spread, combustion-generated air pollution; applications of combustion processes to engines, rockets, and fire research.

EMAE 459. Advanced Heat Transfer. 3 Units.
Analysis of engineering heat transfer from first principles including conduction, convection, radiation, and combined heat and mass transfer. Examples of significance and role of analytic solutions, approximate methods (including integral methods) and numerical methods in the solution of heat transfer problems. Recommended preparation: EMAE 453.

EMAE 460. Theory and Design of Fluid Power Machinery. 3 Units.
Fluid mechanic and thermodynamic aspects of the design of fluid power machinery such as axial and radial flow turbomachinery, positive displacement devices and their component characterizations. Recommended preparation: Consent of instructor.

EMAE 461. Chemistry of Fire Safe Polymers and Composites. 3 Units.
Chemistry of Fire Safe Polymers and Composites starts with the introduction of characterization techniques used for fire safe materials and combustion phenomena research. General discussion on how reduced flammability of polymers and composites are obtained, for example by additives and preparing intrinsically thermally stable chemical structure and some examples of smart approaches, will be discussed. It also discusses the synthetic methods of preparing high temperature stable polymers in addition to the raw materials used to prepare those materials. Special emphasis will be placed on the thermal stability data obtained by thermogravimetric analysis (TGA) and combustion calorimetry for those fire safe materials. Mechanistic aspects of the flammability of polymers will be explained with special emphasis on the molar contribution of chemical functionality to the heat release capacity. Theoretical derivation of thermokinetic parameters will be explained. In addition, a common sense build-up will be attempted by providing actual numbers associated with those thermokinetic parameters. Upon completion of background formation, a more advanced materials, composites and nanocomposites, will be discussed using the results recently reported. Preliminary attempts to explain flame retardation by nanocomposite structures will also be discussed. Offered as EMAC 461 and EMAE 461.

EMAE 463. Fire Dynamics. 3 Units.
This course introduces compartment fires and burning behavior of materials. Topics include: buoyant driven flow, fire plume, ceiling jet, vent flow, flashover and smoke movement as well as steady burning of liquids and solids; ignition, extinction and flame spread over solids. Recommended Preparation: Elementary knowledge in thermo-fluids is required. Offered as EMAE 463 and EMAC 463. Prereq: EMAE 325 or Requisites Not Met permission.

EMAE 464. Fire Protection Engineering. 3 Units.
This course introduces essentials of fire protection in industry and houses. Topics include: hazard identification (release of flammable gases and their dispersion), fire and explosion hazards, prevention and risk mitigation, fire detection systems, mechanisms of fire extinguishment, evaluation of fire extinguishing agents and systems. Offered as EMAC 464 and EMAE 464.

EMAE 471. Computational Fluid Dynamics. 3 Units.
Finite difference, finite element, and spectral techniques for numerical solutions of partial differential equations. Explicit and implicit methods for elliptic, parabolic, hyperbolic, and mixed equations. Unsteady incompressible flow equations in primitive and vorticity/stream function formulations. Steady and unsteady transport (passive scalar) equations. Offered as EMAE 371 and EMAE 471.

EMAE 475. Finite Element Analysis. 3 Units.
Formulation of the finite element methods for linear analysis of solid structures are presented. Solutions of equilibrium equations in static and dynamic analyses are developed. Finite element methods via computer programing are implemented to obtain solutions to pertinent engineering problems. Recommended preparation: EMAE 401.

EMAE 477. Biorobotics Team Research. 3 Units.
Many exciting research opportunities cross disciplinary lines. To participate in such projects, researchers must operate in multi-disciplinary teams. The Biorobotics Team Research course offers a unique capstone opportunity for undergraduate students to utilize skills they developed during their undergraduate experience while acquiring new teaming skills. A group of eight students form a research team under the direction of two faculty leaders. Team members are chosen from appropriate majors through interviews with the faculty. They will research a biological mechanism or principle and develop a robotic device that captures the actions of that mechanism. Although each student will cooperate on the team, they each have a specific role, and must develop a final paper that describes the research generated on their aspect of the project. Students meet for one class period per week and two 2-hour lab periods. Initially students brainstorm ideas and identify the project to be pursued. They then acquire biological data and generate robotic designs. Both are further developed during team meetings and reports. Final oral reports and a demonstration of the robotic device occur in week 15. Offered as EMAE 377 and EMAE 477. Counts as a SAGES Senior Capstone course.

EMAE 479. Mechanics and Control of Compliant Robotics. 3 Units.
Robots are fundamentally mechanical devices designed to function autonomously or semi-autonomously. In autonomous systems including animals and robots, one of the most important mechanical properties is stiffness. Selective compliance allows robots to grasp a wide range of objects and traverse rougher terrain. A new field of Soft Robotics aims to create robots that are robust, cheap, and safe in close proximity to humans. However, as engineers challenge themselves to make increasingly soft robots, new challenges in design and control need to be addressed. This course will provide an introduction to state of the art in robotics as cyber-physical systems from a fundamental mechanics perspective. Topics include: grasping, wearable assistive locomotion, legged locomotion, locomotion in fluids, and locomotion over soft terrain. Offered as EMAE 379 and EMAE 479.

EMAE 480. Fatigue of Materials. 3 Units.
Fundamental and applied aspects of metals, polymers and ceramics. Behavior of materials in stress and strain cycling, methods of computing cyclic stress and strain, cumulative fatigue damage under complex loading. Application of linear elastic fracture mechanics to fatigue crack propagation. Mechanisms of fatigue crack initiation and propagation. Case histories and practical approaches to mitigate fatigue and prolong life.

EMAE 481. Advanced Dynamics I. 3 Units.
Particle and rigid-body kinematics and dynamics. Inertia tensor, coordinate transformations and rotating reference frames. Application to rotors and gyroscopes. Theory of orbital motion with application to earth satellites. Impact dynamics. Lagrange equations with applications to multi-degree of freedom systems. Theory of small vibrations. Recommended preparation: EMAE 181.

EMAE 482. Propulsion. 3 Units.
Energy sources of propulsion. Performance criteria. Review of one-dimensional gas dynamics. Airbreathing engine cycle analysis and turbomachinery. Introduction of thermochemistry and combustion. Rocket flight performance and rocket staging. Chemical liquid and solid rockets. Offered as EMAE 382 and EMAE 482.

EMAE 483. Flight Mechanics. 3 Units.
Aircraft performance: take-off and landing, unaccelerated flight, range and endurance, flight trajectories. Aerodynamics and propulsion. Aircraft static stability and control, simple maneuvers. Aircraft flight dynamics and control, flight simulation. Offered as EMAE 383 and EMAE 483.

EMAE 487. Vibration Problems in Engineering. 3 Units.
Free and forced-vibration problems in single and multi-degree of freedom damped and undamped linear systems. Vibration isolation and absorbers. Modal analysis and approximate solutions. Introduction to vibration of continuous media. Noise problems. Laboratory projects to illustrate theoretical concepts and applications. Recommended preparation: EMAE 181 and MATH 224.

EMAE 488. Advanced Robotics. 3 Units.
This course will focus on up-to-date knowledge and theories related to robotics and multi-agent systems. Related mathematics and theories including group theory (Lie groups), rigid-body motions (SO(3) and SE(3)), kinematics, dynamics, and control will be studied. In addition, the class will also discuss structural, computational and task complexity in robotic systems based on combinatorial analysis, information theory, and graph theory. Lecture and discussion topics: Kinematics; Introduction to Group Theory and Lie Groups; Rigid-body Motions (SO(3), SE(3)); Multi-body Dynamical Systems: Order-N computational methods; Complexity Analysis for Robotic Systems; Structural complexity, information-theoretic complexity, and task complexity; Special Discussion Topics; Special discussion topics may vary each year. Students enrolled in this class will be required to conduct a final project. Two or three students will work as a team. The topics for student teams may include: computer simulation of multi-body dynamical systems, art robot design, and complexity analysis for coupled complex systems. The detailed information will be provided in the first week of the class. The final presentations and demonstrations will be held during the last week of class and will be open to the public audience. Students are also required to submit a final report following a IEEE conference paper template.

EMAE 489. Robotics I. 3 Units.
Orientation and configuration coordinate transformations, forward and inverse kinematics and Newton-Euler and Lagrange-Euler dynamic analysis. Planning of manipulator trajectories. Force, position, and hybrid control of robot manipulators. Analytical techniques applied to select industrial robots. Recommended preparation: EMAE 181. Offered as CSDS 489, ECSE 489 and EMAE 489.

EMAE 494. Energy Systems. 3 Units.
The overarching goal of this course is to introduce energy systems to graduate students, allowing the class to explore energy resource options and technologies. We will evaluate (from a scientific, mathematical and societal perspective) the trade-offs and uncertainties of various energy systems and explores a framework for assessing solutions. Topics will include resource estimation, environmental effects and economic evaluations of fossil fuels, nuclear power, hydropower, solar energy and more. Prereq: Junior or Senior Undergraduate Engineering major or Graduate Engineering major.

EMAE 500S. Graduate Seminar II. 0 Unit.
This course will expose the Ph.D. candidate to research in the fields of Mechanical and Aerospace Engineering in the form of seminars given by invited speakers, faculty candidates, and other graduate students and postdocs within the department. The student must attend a minimum of 8 seminars during the semester to earn a Pass, which can be any combination of departmental seminars, special invited seminars (including faculty candidates), and/or the student seminar series. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 500T. Graduate Teaching II. 0 Unit.
This course will engage the Ph.D. candidate in a variety of teaching experiences that will include direct contact (for example, teaching, recitations and laboratories, guest lectures, office hours) as well non-contact preparation (exams, quizzes, demonstration) and grading activities. The teaching experience will be conducted under the supervision of the faculty member(s) responsible for coordinating student teaching activities. All Ph.D. candidates enrolled in this course sequence will be expected to perform direct contact teaching at some point in the sequence. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 540. Advanced Dynamics II. 3 Units.
Using variational approach, comprehensive development of principle of virtual work, Hamilton's principle and Lagrange equations for holonomic and non-holonomic systems. Hamilton's equations of motion, canonical transformations, Hamilton-Jacobi theory and special theory of relativity in classical mechanics. Modern dynamic system formulations.

EMAE 554. Turbulent Fluid Motion. 3 Units.
Mathematics and physics of turbulence. Statistical (isotropic, homogeneous turbulence) theories; success and limitations. Experimental and observational (films) evidence. Macrostructures and microturbulence. Other theoretical approaches. Recommended preparation: EMAE 454.

EMAE 557. Convective Two-Phase Flow and Heat Transfer. 3 Units.
Basic two-phase flow equations, homogeneous model, drift-flux model, flow regimes, pressure drop in two-phase flow. Nucleation and bubble dynamics, pool boiling, subcooled boiling, forced convection boiling, critical heat flux in pool boiling, critical heat flux in forced convection boiling, minimum heat flux, film boiling, post dryout heat transfer. Flow instabilities, choking in two-phase flow, film and dropwise condensation. Applications to heat exchangers. Special boiling and two-phase flow problems.

EMAE 558. Conduction and Radiation. 3 Units.
Fundamental law, initial and boundary conditions, basic equations for isotropic and anisotropic media, related physical problems, steady and transient temperature distributions in solid structures. Analytical, graphical, numerical, and experimental methods for constant and variable material properties. Recommended preparation: Consent of instructor.

EMAE 560. Sustainable Manufacturing. 3 Units.
This course focuses on sustainable manufacturing principles and analysis methods including material flow analysis, energy flow analysis, life cycle assessment, and Taguchi method, etc., and covers a comprehensive list of manufacturing processes from conventional manufacturing such as metal casting and machining, to emerging manufacturing techniques like additive manufacturing and nano-manufacturing on their sustainable manufacturing operations and practices. Some of the important goals of this course are: a. Students learn to understand the fundamental methods and techniques of sustainable manufacturing. b. Students learn the theory and practices on sustainable manufacturing through sustainability analysis and improvement of industrial manufacturing processes. c. Students learn state-of-the-art knowledge on environmental impact assessment methods. d. Students apply the learned knowledge and skills in class discussions and project implementation. Prereq: Graduate student standing.

EMAE 600S. Graduate Seminar III. 0 Unit.
This course will expose the Ph.D. candidate to research in the fields of Mechanical and Aerospace Engineering in the form of seminars given by invited speakers, faculty candidates, and other graduate students and postdocs within the department. The student must attend a minimum of 8 seminars during the semester to earn a Pass, which can be any combination of departmental seminars, special invited seminars (including faculty candidates), and/or the student seminar series. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 600T. Graduate Teaching III. 0 Unit.
This course will engage the Ph.D. candidate in a variety of teaching experiences that will include direct (for example, teaching recitations and laboratories, guest lectures, office hours) as well non-contact preparation (exams, quizzes, demonstrations) and grading activities. The teaching experience will be conducted under the supervision of the faculty member(s) responsible for coordinating student teaching activities. All Ph.D. candidates enrolled in this course sequence will be expected to perform direct contact teaching at some point in the sequence. Recommended preparation: Ph.D. student in Mechanical Engineering.

EMAE 601. Independent Study. 1 - 18 Units.

EMAE 651. Thesis M.S.. 1 - 18 Units.
(Credit as arranged.)

EMAE 689. Special Topics. 1 - 18 Units.

EMAE 695. Project M.S.. 1 - 9 Units.
Research course taken by Plan B M.S. students. Prereq: Enrolled in the EMAE Plan B MS Program.

EMAE 701. Dissertation Ph.D.. 1 - 9 Units.
(Credit as arranged.) Prereq: Predoctoral research consent or advanced to Ph.D. candidacy milestone.