Department of

Mechanical and Aerospace Engineering

College of Engineering

Head: Trustee Professor *J. Clair Batty*, thermal science, cryogenics, space systems
Office in Engineering Laboratory 178, (435) 797-2867

FAX (435) 797-2417
Undergraduate/Graduate E-mail jpsmith@mae.usu.edu
WWW http://www.mae.usu.edu/

Professors *P. Thomas Blotter*, structural dynamics; *Alma P. Moser,* (associate dean, College of Engineering), engineering mechanics, piping systems; *Warren F. Phillips,* aerodynamics, flight mechanics; *Frank J. Redd*, space systems; *Robert E. Spall*, thermal/fluids; **Adjunct Professor** *Dell K. Allen*, manufacturing; **Professors Emeriti** *Ralph H. Haycock*, mechanics, manufacturing; *Russell M. Holdredge*, heat transfer, fluid mechanics; *Owen K. Shupe*, nuclear, material science; *Carl D. Spear*, material science; *Edward W. Vendell, Jr.*, cryogenics, heat transfer, thermal systems design; **Associate Professors** *Steven L. Folkman*, applied mechanics, structural dynamics, space structures; *Thomas H. Fronk*, mechanics of composites and materials; *R. Rees Fullmer*, manufacturing, controls, robotics, dynamics, spacecraft; *Carl G. Wood,* design, manufacturing; **Research Associate Professor** *Sue Ellen Haupt,* fluid mechanics, atmospheric sciences; **Assistant Professors** *Elgin A. Anderson*, thermal/fluids; *Ning Fang,* manufacturing; *Barton L. Smith,* thermal/fluids; **Adjunct Assistant Professors** *Scott M. Jensen,* thermal management of space systems; *Paul J. Mueller,* thermal science, propulsion; *Steven R. Wassom,* controls, dynamic spaceflight

Degrees offered: Bachelor of Science (BS), Master of Engineering (ME), Master of Science (MS), and Doctor of Philosophy (PhD) in Mechanical Engineering; BS in Manufacturing Engineering

Undergraduate Emphasis: *Mechanical Engineering*—Aerospace Engineering

Graduate specializations: Aerospace Engineering, Dynamics and Controls, Manufacturing Engineering, Solid Mechanics, Thermal/Fluids

Undergraduate Programs

Mission

The Department of Mechanical and Aerospace Engineering provides graduates with a foundation of knowledge and experience upon which to build successful careers in mechanical, manufacturing, or aerospace engineering, or other fields where a strong engineering background is required or desirable. Undergraduate programs emphasize mechanical engineering fundamentals and computer-based problem solving, while teaching students to learn, synthesize, and communicate engineering information. Graduate programs emphasize fundamental and applied research, providing students with enhanced preparation for engineering practice, research, and education. Students, faculty, and staff are committed to excellence in learning, discovery, and engagement in an environment that fosters diversity and mutual respect.

Undergraduate Program Objectives (Mechanical Engineering)

1. Graduates will succeed in entry-level engineering positions with mechanical, manufacturing, or aerospace firms in regional, national, or international industries, as well as with government agencies.

2. Graduates will succeed in the pursuit of advanced degrees in engineering or other fields where a solid foundation in mathematics, science, and engineering fundamentals is required.

3. Graduates will be able to synthesize mathematics, science, engineering fundamentals, and laboratory and work-based experiences to formulate and solve engineering problems in both thermal and mechanical systems areas.

4. Graduates will have proficiency in computer-based engineering, including modern numerical methods, software design and development, and the use of computational tools.

5. Graduates will be prepared to communicate and work effectively on team-based engineering projects.

6. Graduates will recognize the importance of, and have the skills for, continued independent learning.

Undergraduate Program Outcomes (Mechanical Engineering)

Fundamentals

Students will identify, formulate, and solve basic engineering problems utilizing:

1. linear algebra
2. calculus-based statistics
3. multivariable calculus
4. differential equations
5. calculus-based physics
6. chemistry
7. material science
8. solid mechanics
9. fluid mechanics
10. thermal science
11. manufacturing science

Communication

Students will develop and demonstrate the ability to communicate engineering information, including geometry, technical concepts, and results, by:

1. participating in oral presentations.
2. writing proposals and reports.
3. developing engineering drawings and specifications.
4. participating in team-based engineering projects.

Laboratory Experiences

Students will participate in and evaluate laboratory experiences, which:

1. include experimental design, data collection, and data analyses.
2. incorporate the use of modern laboratory and data acquisition equipment.
3. utilize statistical analysis and interpretation of data.
4. develop basic manufacturing skills.
5. may include work-based learning experiences, such as internships.

Computer-based Engineering

Students will demonstrate proficiency in the application of computer technology to engineering problem-solving through:

1. application of modern numerical methods and computational techniques.
2. design and development of engineering software.
3. integration of numerical solutions into the engineering process of design and analysis.
4. use of current commercial engineering software.

Humanities and Social Sciences

Students will acquire significant exposure to the humanities and social sciences, so as to:

1. gain an appreciation for the broad impact of engineering solutions on society.
2. demonstrate an understanding of the fundamentals of the history, principles, form of government, and economic system of the United States.
3. demonstrate a knowledge of contemporary global issues.
4. contribute to the development of the individual as a responsible well-rounded citizen.

Design and Synthesis

Students will participate in the design and realization process, in which they will:

1. develop a set of multidisciplinary engineering requirements.
2. synthesize material from mathematics, science, and engineering fundamentals to solve engineering problems.
3. design, develop, and verify software to solve engineering problems.
4. bring a system from requirements definition to concept development, then specification, prototype and testing, and production or fabrication using significant engineering analysis.
5. demonstrate the links between design, prototyping, testing, manufacturing, and other disciplines.
6. manage a project, including budgeting and detailed planning.

Independent Learning

Students will recognize the importance of, and demonstrate the skills required for, independent learning through:

1. independent study required in the engineering curriculum.
2. exposure to case studies in ethics and professional responsibility.
3. exposure to advanced topics in engineering science.
4. exposure to advanced topics in engineering research.
5. studying for and passing the Fundamentals of Engineering Examination.

Assessment and Quality Improvement

The MAE faculty and staff are committed to excellence and to continuous quality improvement. A responsive assessment and feedback process involving major constituencies, including faculty, students, alumni, and industrial employers of students and graduates, is in place and ongoing.

Options for Undergraduate Study

The **Mechanical Engineering** BS degree provides the broadest background of any discipline in the field of engineering. Mechanical Engineering graduates are prepared to pursue careers in such widely diverse industries as aerospace, agricultural equipment, automotive, biotechnical, chemical processing, composite materials, computer equipment, defense, electrical utilities, food processing, industrial equipment, manufacturing, materials processing, nuclear, petroleum, robotics, and solar energy. Most Mechanical Engineering graduates are prepared for graduate studies and enhanced career prospects in engineering or other areas, such as consulting, law, medicine, business management, or teaching. In addition, students who are preparing to apply for admission to medical school will find that Mechanical Engineering provides an excellent foundation for the increasingly technology-oriented field of medicine.

The **Aerospace Engineering** emphasis within the Mechanical Engineering BS degree serves to focus mechanical engineering fundamentals on the mechanics and dynamics of both flight within the atmosphere and space flight. Included within its scope are studies in aerodynamics, aircraft flight dynamics and control, aircraft design, spacecraft orbital mechanics, spacecraft attitude motion and control, and space systems design. Graduates who complete the aerospace engineering emphasis are prepared to pursue careers in aircraft design and development, aircraft flight testing, spacecraft and space systems design, and spacecraft trajectory design and analysis. As fully qualified Mechanical Engineers, graduates with the aerospace engineering emphasis are also well-prepared to pursue graduate studies or careers in the industries listed above under Mechanical Engineering.

The **Manufacturing Engineering** BS degree prepares students to be proficient in the fundamentals of engineering, as well as in materials and manufacturing processes; process, assembly, and product engineering; manufacturing competitiveness; manufacturing systems design; and laboratory experience. Graduates will understand the behavior and properties of materials as they are altered and influenced by processing in manufacturing; the design of products and the equipment, tooling, and environment necessary for their manufacture; the creation of competitive advantage through manufacturing planning, strategy, and control; the analysis, synthesis, and control of manufacturing operations using statistical and calculus based methods; and how to measure manufacturing process variables and make technical inferences about the process. Graduates will have the necessary background to pass the Certified Manufacturing Technologist and Certified Manufacturing Engineer exams. Graduates who complete the Manufacturing Engineering degree are prepared to pursue graduate studies or careers in any industry that manufactures a product. For example, the aerospace, automotive, electronics, machine tool, petroleum, and electronics industries all employ manufacturing engineers as product designers, process designers and managers, maintenance engineers, and quality control engineers.

The first two years of the MAE curriculum are structured to concentrate on the fundamentals of mathematics, chemistry, physics, computer science, and basic engineering science. During the second two years, students apply these fundamentals to more concentrated courses in the essentials of mechanical, aerospace, and/or manufacturing engineering. Laboratory activities and computer usage are integrated throughout the curriculum to give students opportunities for hands-on exposure to modern computer hardware and software, as well as other modern hardware and laboratory facilities. Engineering design activities begin during the first two years and progress in depth as the student's proficiency increases. The engineering design experience culminates in a capstone senior design course, integrating the engineering coursework into a focused, realistic design project.

Both the Mechanical Engineering and the Manufacturing Engineering programs are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET). The Aerospace Engineering emphasis is included within the Mechanical Engineering degree.

Admission and Graduation Requirements

Freshman and transfer students must satisfy the admission policies and entrance requirements of both the University and the College of Engineering. Each new student will be assigned an advisor, who will help plan an educational program fulfilling the student's professional goals. Placement of incoming students will depend on high school and/or prior college coursework. Those who complete a portion of the University Studies requirements by examination (CLEP) and/or by advanced placement (AP) credit may complete the requirements for a Bachelor of Science degree in less than four years.

Curriculum. At the beginning of each school year, each student should obtain a detailed, four-year requirement sheet. This sheet, which lists semester requirements for each of the three curricula (mechanical, manufacturing, and aerospace), may be obtained from the departmental office. All students in the department follow the preprofessional engineering curriculum for the freshman and sophomore years. Prior to the junior year, the student must apply for admission to the professional program and, in consultation with the faculty advisor, select an area of emphasis. Students who are unable to take courses during the semester indicated on the curriculum requirement sheet may develop alternative schedules, consistent with prerequisites and the timing of course offerings.

GPA Requirement. A 2.3 GPA in all technical courses is the minimum standard which preprofessional students must attain in order to be considered for admission to any MAE professional program. A 2.0 overall GPA is required to be considered for graduation from any undergraduate program in the Mechanical and Aerospace Engineering Department.

Course Requirements. The specific course requirements for the MAE preprofessional program and the MAE professional programs are quite extensive and may occasionally change. For these reasons, the complete requirements are not listed here. For more information, contact the department or send an Internet e-mail request to **jpsmith@mae.usu.edu**.

A **passing grade on the Fundamentals of Engineering Exam**, the first step in becoming a licensed professional engineer, is required for graduation. Past experience has shown that the USU Mechanical and Aerospace Engineering students are well-prepared for this locally administered, national exam.

For additional information on academic requirements, see the College of Engineering (pages 89-93) and the Undergraduate Graduation Requirements (pages 53-55) sections of this catalog.

Financial Support

Scholarships, assistantships, grants-in-aid, and work-study programs are available to undergraduate students through the University. In addition, the MAE department employs undergraduates to assist in engineering research and development. Aerodynamics, design of instrumentation and payloads for the upper atmosphere and space, buried structures, and manufacturing processes and controls are some of the research programs that involve undergraduate students. Cooperative education and industrial employment opportunities for students are coordinated by the University Placement Office.

Concurrent BS/Master's Program

The concurrent BS/Master's program allows engineering students to begin taking graduate-level classes during their senior year. This permits them to complete requirements for *both* the BS degree *and* the master's degree concurrently during two years. Students in this program have a greater selection of graduate courses, since many graduate courses are taught during alternate years. In addition, the student's senior design project could be a start for a graduate design project or thesis. After completing their BS degree, students in the program can earn a master's degree in only one additional year. Both the BS and the master's degree can generally be earned with 150 total credits, although students should note that a Plan C MS requires 3 extra credits. Finally, students with a master's degree can expect a much higher starting salary following graduation. (For more information, see *College of Engineering* section of this catalog, page 92.)

Graduate Programs

Admission Requirements

All students intending to pursue graduate studies at Utah State University must complete and return an *Application for Admission* to the School of Graduate Studies. In addition to the general graduate admission requirements listed on pages 72-73, the department requires all graduate applicants to have a bachelor's degree from an accredited institution in Mechanical Engineering, Aerospace Engineering, Manufacturing Engineering, or a closely related engineering discipline. A minimum GPA of 3.0 for MS applicants and 3.3 for PhD applicants is required for the last 60 semester or 90 quarter credits earned. All MAE graduate students are expected to be well-acquainted with either the FORTRAN or C programming language. Those students who do not have a BS degree in an appropriate engineering discipline may be admitted with nonmatriculated status and required to complete some remedial requirements. Applicants are also required to submit evidence of potential graduate-level success through GRE scores in the verbal, quantitative, and analytical categories.

Specializations

The Department of Mechanical and Aerospace Engineering offers ME, MS, and PhD degrees in Mechanical Engineering, with specializations in Aerospace Engineering, Manufacturing Engineering, and Mechanical Engineering (including Solid Mechanics, Thermal/Fluids, and Dynamics and Control).

Aerospace Engineering addresses atmospheric and space flight. Included are such disciplines as computational fluid dynamics, experimental fluid mechanics, aerodynamics, aircraft flight dynamics, aircraft design, spacecraft orbital mechanics, spacecraft attitude motion and control, aircraft and spacecraft propulsion systems, space system design, thermal management of space deployed systems, and the space environment. Mechanical Engineering graduates choosing the aerospace specialization may pursue careers in such areas as aircraft design and development, aircraft flight testing, spacecraft and space systems design, and spacecraft trajectory design and analysis, as well as the broader, traditional mechanical engineering fields.

Manufacturing Engineering concentrates on the theory of manufacturing systems, including manufacturing processes, the design of manufacturing systems, product design, productivity, quality, and life cycle analysis. Principal areas of emphasis include manufacturing automation, machining theory, and mold flow analysis, as well as flexible manufacturing systems and computer-integrated manufacturing. Manufacturing engineers are prepared to pursue product and process design careers in any electronics, food processing, and petroleum industries.

Mechanical Engineering deals with the creation of the mechanical systems and machines that serve society. Areas of specialization include solid mechanics, thermal/fluids, and dynamics and control. The **solid mechanics** specialization is concerned with the mechanics of displacement and stress analysis combined with material science for selection of an optimum design. Students learn to use the finite element method as well as classical methods for the determination of stresses, strains, and displacements. Included are studies of elasticity, plasticity, and failure in traditional metals and high-tech composite materials. The **thermal/fluids** specialization is concerned with the transport of mass, momentum, and energy in solids, liquids, and gasses. Included within its scope are the fundamental studies of thermodynamics, heat transfer, and fluid mechanics. The **dynamics and control** specialization is concerned with describing and controlling the motion of mechanical systems. Included within its scope are the fundamental studies of dynamics, kinematics, vibrations, control theory, hydraulics and pneumatics, electromechanical systems, and machine design. Graduates who select the broad mechanical engineering option are prepared to pursue careers in such widely diverse disciplines as aerospace, automotive, building, chemical, defense, electronics, environmental engineering, food processing, heating and air conditioning, heavy equipment, machine tools, manufacturing, nuclear, petroleum, public utilities, and solar energy.

Degree Programs

The **Plan A MS Degree** requires 6 credits of graduate-level coursework in Mechanical Engineering fundamentals; 12 credits of 6000-level (or above) engineering coursework, exclusive of MAE 6930, 6950, 6970, and 6990; a minimum of 3 credits of 5000-level (or above) coursework in approved mathematics; and 9 credits selected from any one of five declared areas of emphasis. A minimum of 30 credits is required beyond the BS, including a 6-credit thesis (MAE 6970). The thesis must meet School of Graduate Studies requirements. A paper with the student as author or coauthor, submitted for publication in a refereed journal, is also required.

The **Plan C MS Degree** requires 6 credits of graduate-level coursework in Mechanical Engineering fundamentals; 18 credits of 6000-level (or above) engineering coursework, exclusive of MAE 6930, 6950, 6970, and 6990; a minimum of 3 credits of 5000-level (or above) coursework in approved mathematics; and either 12 credits selected from any one of five declared areas of emphasis, or 15 credits selected from any two of the areas. A minimum of 33 credits is required beyond the BS, which may not include a thesis (MAE 6970), but may include up to 3 credits of Design Project (MAE 6950). MAE 6950 requires a report written to thesis standards.

The **Master of Engineering Degree** requires 6 credits of graduate-level coursework in Mechanical Engineering Fundamentals; 15 credits of 6000-level (or above) engineering coursework exclusive of MAE 6930, 6950, 6970, 6990, 7930, 7970, and 7990; a minimum of 3 credits of 5000-level (or above) coursework in approved mathematics; and either 15 credits selected from Group A or at least 9 credits from Group A and the remainder chosen from Group B. A minimum of 30 credits is required beyond the BS, which may not include a thesis (MAE 6970), but may include up to three credits of Design Project (MAE 6950). MAE 6950 requires a report written to thesis standards. Students are not required to defend the report. However, the report must be approved by the major professor.

The **PhD Degree** requires 12 credits of graduate-level coursework in Mechanical Engineering fundamentals; 24 credits of 6000-level (or above) engineering coursework, exclusive of MAE 6930, 6950, 6970, 6990, 7930, 7970, and 7990; a minimum of 6 credits of 5000-level (or above) coursework in approved mathematics; and 18 credits selected from any one of five declared areas of emphasis. A minimum of 90 credits is required beyond the BS, including a dissertation (MAE 7970). The dissertation must meet School of Graduate Studies requirements and be at least 24 credits, but no more than 30 credits. A paper with the student as author or coauthor, submitted for publication in a refereed journal, is also required.

GPA Requirement. A 3.0 GPA is the minimum acceptable for an ME, MS, or PhD degree from Utah State University.

Course Requirements. The specific course requirements for the ME, MS, and PhD degrees offered through the department may occasionally change. For this reason, prospective students are advised to seek current details concerning graduate degree requirements and program coursework by contacting the department or sending an Internet e-mail request to: **jpsmith@mae.usu.edu**

Research

The Department of Mechanical and Aerospace Engineering is conducting research in all of the areas of specialization listed above. Departmental research projects are funded by both government agencies and private industry. Current research topics include analytical and experimental structural dynamics, computational and experimental fluid dynamics, aerodynamics, plastics and composite materials, numerical modeling and design of composite structures, buried structures, thermodynamics, heat transfer, cryogenics, intelligent control systems, manufacturing automation, spacecraft control, design and analysis of space systems, orbital mechanics, remote sensing, robotics, life-cycle engineering, design theory and methodology, and production modeling and simulation.

Financial Assistance

A number of teaching and research assistantships are available to graduate students through the department, and are awarded on a competitive basis each year. In addition, scholarships covering the nonresident portion of tuition are available each semester, on a competitive basis, to nonresident students who hold a graduate assistantship paying at least $250 per month. Students interested in working part time as teaching or research assistants should apply to the department by March 31 for the coming academic year.

Acceptance to pursue graduate studies in the Department of Mechanical and Aerospace Engineering does not imply a commitment to any type of financial aid. All awards for financial aid are made on a competitive basis after applicants are admitted to graduate school. All students who receive any type of financial support from the University or who are supplied University space for study or research must carry a minimum of 9 credits of approved coursework each semester while receiving such support.

Mechanical and Aerospace Engineering Courses (MAE)

MAE 1200. Engineering Graphics. Introduction to technical sketching, solid modeling, and engineering graphics. Concurrent engineering design process applied to a project. Students start with hand sketches, then move through variational geometry solid models, with tolerance analysis and control, until they have produced a complete set of manufacturing drawings conforming to the ASME standard. Prerequisite: Math 1060. (2 cr) (F,Sp)

MAE 2060. Material Science. Study of atomic and microscopic structures of metals, polymers, ceramics, and composite materials, and how these structures affect material properties. Prerequisite: Chem 1210. (3 cr) (F,Sp)

MAE 2200. Engineering Numerical Methods I. Introduction to computational methods, emphasizing software development using FORTRAN 95. Prerequisite: Math 1220. (2 cr) (F)

MAE 2210. Engineering Numerical Methods II. Explores basic tools of numerical analysis, solution to ordinary and partial differential equations, software development using FORTRAN 95, and applications using computer algebra packages. Prerequisites: MAE 2200; Math 2210, 2250 (may be taken concurrently). (3 cr) (Sp)

MAE 2250. Cooperative Practice. Planned work experience in industry. Detailed program must have prior approval. Written report required. (3 cr) (F,Sp,Su)

MAE 2400. Thermodynamics I. First and second laws of thermodynamics; analysis of open and closed systems; equations of state; power and refrigeration cycles; and problem solving methodology. Prerequisites: Math 1220; Math 2210 (may be taken concurrently). (3 cr) (F,Sp,Su)

MAE 2600. Manufacturing Processes. Introduction to manufacturing processes and CAD/CAM. Material forming, machining, finishing, and joining. Integration of manufacturing and CAD, plus the fundamentals and application of statistical process control. Prerequisite: MAE 2060 (may be taken concurrently). (3 cr) (Sp)

MAE 3040. Mechanics of Solids. Stress, strain, and deflection due to flexure and shear. Combined stresses, instability, nonsymmetric bending, torsion, and energy methods. Prerequisite: Engr 2040. (3 cr) (F)

MAE 3320. Advanced Dynamics. Particle and rigid body dynamics. Work and kinetic energy, conservation of energy, impulse-momentum, conservation of linear and angular momentum. Kinematics and kinetics in 2-D and 3-D. Newtonian and Lagrangian Mechanics. Prerequisites: Engr 2020; MAE 2200 (may be taken concurrently). (3 cr) (F)

MAE 3340. Instrumentation and Measurements. Principles and application of mechanical instrumentation and experimentation. Sensing elements, signal conditioning, data acquisition, statistical analysis of data, and instrumentation system design. Prerequisites: Engr 2040 and ECE 2200. (3 cr) (Sp)

MAE 3400. Thermodynamics II. Second law analysis, power and refrigeration cycles, property relations, gas mixtures, psychrometrics, chemical reactions, chemical equilibrium, introduction to heat transfer, steady state and transient conduction. Prerequisites: MAE 2400; MAE 2200 (may be taken concurrently). (3 cr) (F)

MAE 3420. Fluid Dynamics. Application of fluid dynamic theory to inviscid and viscous, incompressible and compressible, and external and internal fluid flows, with emphasis on laminar and turbulent boundary layers. Must be taken concurrently with MAE 2200. Prerequisites: Engr 2020, MAE 2400. (3 cr) (F)

MAE 3440 (QI). Heat and Mass Transfer. Introduction to convection, external flow, internal flow, free convection, boiling and condensation, heat exchangers, radiation and diffusion mass transfer. Includes design project. Prerequisites: MAE 3400, 3420; MAE 2210 (may be taken concurrently). (3 cr) (Sp)

MAE 3800. Design I. First course in senior design sequence. Design process, teaming skills, engineering economics, project selection and management, proposal writing, technical writing, and technical presentations. Prerequisite: Engr 2040. (2 cr) (Sp)

MAE 4300. Machine Design. Computer-aided design and synthesis of mechanisms, mechanical linkages, cams, fasteners, welds, gears, bearings, power transmission components, and lubrication. Component failure analysis based on metal fatigue related to dynamic loading. Prerequisite: MAE 3040. (4 cr) (Sp)

MAE 4400 (CI). Fluids/Thermal Laboratory. Laboratory experiences in observation and measurement of fundamental fluid and thermal phenomena. Prerequisites: MAE 3340, 3440. (1 cr) (F)

MAE 4800 (CI). Design II. Senior design project, including a technical presentation and a critical design review. Prerequisites: MAE 3440, 3800, 4300. (3 cr) (F)

MAE 5020. Finite Element Methods in Solid Mechanics I. Introduction to finite element methods and their application to the analysis and design of mechanical engineering systems. Prerequisite: MAE 3040. Also taught as CEE 5020. (3 cr) (F)

MAE 5060. Mechanics of Composite Materials I. Stress-strain relations for nonisotropic composites, such as fiber-reinforced plastic laminates, properties and their uses, strength and life determination, and methods for design using composite materials. Prerequisite: MAE 3040 or CEE 3010. Also taught as CEE 5060. (3 cr) (Sp)

MAE 5300. Vibrations. Vibration of single and multiple degree of freedom, and discrete mass systems. Natural frequencies and mode shapes for free, damped, and undamped sytems. Forcing functions and transient responses. Matrix methods, numerical solution, and random vibrations. Applications and design. Prerequisites: Engr 2020, 2040. (3 cr) (F)

MAE 5310. Dynamic Systems and Controls. Study of continuous-time systems, classical and modern systems design methods, transfer function models, state space, dynamics of linear systems, and frequency domain analysis and design techniques. Introduction to controllability and observability, and full-state pole placement controller design. Laboratory work required. Prerequisite: MAE 3340. (3 cr) (F)

MAE 5400. Heating and Air Conditioning. Air conditioning and heating, solar utilization, thermal environmental control, computational methods, and design project. Prerequisites: MAE 3400, 3420. (3 cr) (F)

MAE 5420. Compressible Fluid Flow. Application of conservation of mass, momentum, and energy to the design and analysis of compressible fluid systems. Prerequisites: MAE 3400, 3420. (3 cr) (Sp)

MAE 5440. Computational Fluid Dynamics I. Introduction to computational fluid dynamics and heat transfer using the finite-volume method. Extensive code development. Application of a commercial CFD solver to a problem of interest. Prerequisites: MAE 3420 and 3440. (3 cr) (Sp)

MAE 5500. Aerodynamics. Fundamentals of incompressible, inviscid flow; aerodynamic forces and moments; airfoil characteristics; incompressible flow around two-dimensional airfoils and finite wings; three-dimensional incompressible flow; and introduction to aircraft performance. Prerequisite: MAE 3420. (3 cr) (F)

MAE 5510. Dynamics of Atmospheric Flight. Aircraft equations of motion; aerodynamic forces and moments; aircraft stability and control in roll, pitch, and yaw; aircraft motion with six degrees of freedom; aircraft performance and design; and design project. Prerequisite: MAE 5500. (3 cr) (Sp)

MAE 5520. Dynamics of Space Flight. Classical astrodynamics, including orbital mechanics, orbit determination, orbital maneuvers, earth-orbiting and interplanetary trajectories; spacecraft attitude motion and control, gyroscopic instruments; introduction to spacecraft propulsion. Prerequisite: MAE 3320. (3 cr) (F)

MAE 5600. Manufacturing Process Planning and Statistical Quality Control. Explores how to produce products in today's manufacturing environment. Topics include forecasting, planning, facility layout, job design, planning, scheduling, total quality management, and statistical process control as they relate to manufacturing firms. Prerequisite: MAE 2600. (3 cr) (F)

MAE 5610. Hydraulics and Pneumatics. Hydraulic and pneumatic circuit theory, components, and systems analysis and design. Efficiency and performance evaluation, based on steady and transient flow principles and force and energy transfer concepts. Introduction to electrohydraulic control systems. Prerequisite: MAE 3420. (3 cr) (Sp)

MAE 5620. Manufacturing Automation. Principles of automation technology as applied to manufacturing systems. Topics include motion control, PLC, robotics, CNC, and system integration. Prerequisite: MAE 2600. (3 cr) (F)

MAE 5630. Machining Theory and Applications. Introduces fundamental metal cutting theory (such as chip formation, cutting forces and temperatures, and tool wear) and its applications, including high-speed machining of aerospace and other difficult-to-machine alloys. Prerequisites: MAE 2600 and 3040. (3 cr) (Sp)

MAE 5640. Design for Manufacturability. Product design for economic production. Manufacturing processes (especially primary processes), associated tooling cost and design, and resultant product design requirements. Prerequisites: MAE 2600 and 3800. (3 cr) (Sp)

MAE 5680. Manufacturing Planning and Simulation. Explores planning and simulation methods for process design issues in electronics manufacturing (EM) and discrete parts manufacturing. Students learn planning, modeling, and simulation methods at the process and system level. Prerequisite: MAE 5600. (3 cr) (Sp)

MAE 5900. Cooperative Practice. Planned work experience in industry. Detailed program must have prior approval. Written report required. Student must be in professional program. (3 cr) (F,Sp,Su)

MAE 5930. Special Problems. Formulation and solution of practical or theoretical problems. Prerequisite: Permission of department head. (1-3 cr) (F,Sp,Su) ®

*****MAE 6010. Finite Element Methods in Solid Mechanics II.** Advanced theory and applications of finite element methods to both static and dynamic solid mechanics problems. Prerequisite: MAE 5020. Also taught as CEE 6010. (3 cr) (Sp)

MAE 6040. Continuum Mechanics and Elasticity. Mechanics of continuous media; tensors, stress, strain, deformation, rate equations, and constitutive equations. Plane stress, plane strain, torsion, and bending theories, as well as problem solutions, investigated for linear elastic materials. Prerequsite: MAE 3040 or CEE 3010. (3 cr) (F)

MAE 6050. Experimental Methods in Structural Engineering. Experimental techniques used in research and design in structural engineering and mechanics. Structural models. Theory and practical applications. Development of principles used to design research projects. Prerequisite: Instructor's consent. Also taught as CEE 6050. (3 cr) (Sp)

*****MAE 6070. Mechanics of Composite Materials II.** Second course in composite materials. Stress-strain states of laminated composite structures, including interlaminar stresses, failure criteria, and hygrothermal stresses. Prerequisite: MAE 5060. Also taught as CEE 6070. (3 cr) (Sp)

MAE 6090. Theory of Plates and Shells. Introduction to plate and shell theories. Development of bending and buckling of plates and shells through classical theory. Prerequisite: MAE 3040 or CEE 3010. Also taught as CEE 6090. (3 cr) (Su)

MAE 6130. Structural Dynamics and Seismic Design. Development and solutions for equations of motion for single- and multi-degree of freedom systems. Dynamic analysis by Modal Superposition and Response Spectra. Design of structures for seismically active areas. Also taught as CEE 6130. (3 cr) (Sp)

*****MAE 6180. Dynamics and Vibrations.** Fundamentals of two-dimensional and three-dimensional rigid body dynamics, including Newtonian, Lagrangian, and Leavit Energy Methods. Equations of motion, mode shapes, and natural frequencies for continuous media and multi degree-of-freedom systems. Prerequisite: MAE 5300 or CEE/MAE 6130. Also taught as CEE 6180. (3 cr) (F)

MAE 6320. Linear Multivariable Control. Modeling, analysis, and design of multi-input, multi-output control systems, including both state space and transfer matrix approaches, with an emphasis on stability. Prerequisite: ECE 4310, MAE 5310, or equivalent. Also taught as ECE 6320. (3 cr) (F)

MAE 6330. Nonlinear and Adaptive Control. Methods of nonlinear and adaptive control system design and analysis. Includes qualitative and quantitative theories, graphical methods, frequency domain methods, sliding surface design, linear parameter estimation methods, and direct and indirect adaptive control techniques. Prerequisite: ECE/MAE 6320. Also taught as ECE 6330. (3 cr) (Sp)

*****MAE 6340. Spacecraft Attitude Control.** Spacecraft attitude dynamics and controls. Spin stabilized, three axis, and dual spin modes. Attitude determination techniques. Prerequisite: ECE 5320. Also taught as ECE 6340. (3 cr) (F)

*****MAE 6350. Robotics.** Fundamentals of robotic systems, including kinetics, kinematics, sensors, actuators, control algorithms, motion planning, and computer systems. Integration of critical design components to develop complete systems. Robotic manipulator analysis and design. Applications in manufacturing. Mobile rockets, including wheeled, legged, and alternative locomotion robots. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as ECE 6350. (3 cr) (Sp)

MAE 6410. Fluid Dynamics. Basic laws of fluid motion, Navier Stokes equations, kinematics of the flow field, fundamental exact solutions of viscous flow, and elements of turbulence. Prerequisite: MAE 3420 or CEE 3500. (3 cr) (F)

*****MAE 6420. Experimental Methods in Fluid Mechanics.** Explores process and techniques involved in acquisition, analysis, and presentation of experimental data, with particular emphasis on aerodynamic applications. Topics include digital signal processing, statistics, uncertainty analysis, hot wire anemometry, and wind tunnel testing. Prerequisite: MAE 3420. (3 cr) (Sp)

*****MAE 6430. Boundary Layer Theory.** Topics include derivation of the boundary layer equations; exact, approximate, and numerical solution techniques; quasi-cylindrical swirling flows; boundary layers in compressible flow; separation; nonsteady boundary layers; stability and transition; and turbulent boundary layers. Prerequisite: MAE 6410. (3 cr) (Sp)

MAE 6440. Computational Fluid Dynamics II. Advanced topics in computational fluid dynamics using the finite-volume method, including body-fitted nonorthogonal grids and grid generation, efficient linear solvers, and turbulence modeling. Extensive code development. Prerequisite: MAE 5440. (3 cr) (Su)

*****MAE 6450. Thermodynamics.** Topics in classical and statistical thermodynamics, including distribution functions, free molecular flow, electron and photon gas modeling, derived properties of solids, and thermodynamic applications in areas of current research interest. Prerequisite: MAE 3400. (3 cr) (F)

*****MAE 6460. Conduction Heat Transfer.** Integral, differential, and numerical methods for solving engineering problems associated with the diffusion of heat in a rigid solid. Prerequisite: MAE 3440. (3 cr) (Sp)

*****MAE 6470. Convection Heat Transfer.** Integral, differential, and numerical methods for solving engineering problems associated with transfer of heat in a viscous fluid. Prerequisites: MAE 3420, 3440. (3 cr) (Sp)

*****MAE 6480. Radiation Heat Transfer.** Radiation theory and applications. Includes utilization of computer software. Prerequisite: MAE 3440. (3 cr) (F)

*****MAE 6490. Turbulence.** Fundamentals of turbulent fluid flow, with emphasis on providing student with sufficient physical and mathematical background to critically evaluate current literature and make original research contributions. Topics include stochastic tools, the governing equations, transition to turbulence, isotropic turbulence, measurement techniques, and free and wall bounded turbulent shear flows. Prerequisite: MAE 6410 or instructor's consent. (3 cr) (Sp)

MAE 6530. Propulsion Systems. Fundamentals of turbine and rocket propulsion, including nozzle theory and thermodynamic relations, combustion processes, and flight performance. Rocket propulsion topics, including solid, liquid, and hybrid rocket engines; and advanced engine concepts. Turbine engine propulsion systems, including turbojets, turbofans, afterburners, and advanced unducted fan concepts. Prerequisite: MAE 5420. (3 cr) (Sp)

*****MAE 6540. Astrodynamics.** Advanced topics in astrodynamics to include: general and special perturbations, universal variable, methods of orbit determination, Lambert's theorem, the restricted three-body problem, and space mission planning. Prerequisite: MAE 5520. (3 cr) (Sp)

***MAE 6570. Potential Fluid Flow.** Application of the principles and methods of classical hydrodynamics to the solution of problems. Closed form solution to invisual fluid flows obtained using complex variables and conformal mappings. Prerequisite: CEE 3510 or MAE 3420. Also taught as CEE 6570. (2 cr) (F)

MAE 6640. Life Cycle Engineering. Familiarizes students with re-engineering, cost/benefit analysis, value engineering, and life cycle design. Students will analyze costs and benefits of design decisions over the product life (needs, market, use, service, reliability, retirement, etc.) while improving the life cycle design of industrial products. Prerequisite: Graduate standing or permission of instructor. (3 cr) (F)

*****MAE 6800. Advanced Machine Design.** Advanced topics in fluid film and boundary lubrication. Dynamics and vibration consideration in design of machine systems and fatigue failure theories. Prerequisite: MAE 4300. (3 cr) (Sp)

MAE 6900. Seminar. Overview of graduate program requirements, current research, and research opportunities. Presentations from graduate students, faculty, and outside speakers. Master's degree candidates must include 1 credit and doctoral degree candidates must include 2 credits of MAE 6900 in an approved program of study. Prerequisite: Graduate standing or approval of department head. (0.5 cr) (F,Sp) ®

MAE 6930. Special Problems. Independent or group study of engineering problems not covered in regular course offerings. (1-3 cr) (F,Sp,Su) ®

MAE 6950. Design Project. Individual projects involving the design, development, and/or testing of components, devices, or systems. Formal report required. (3 cr) (F,Sp,Su)

MAE 6970. Thesis Research. (1-9 cr) (F,Sp,Su) ®

MAE 6990. Continuing Graduate Advisement. (1-12 cr) (F,Sp,Su) ®

*****MAE 7040. Elasticity.** Energy theorems, variational techniques, complex variable solutions, and three-dimensional solutions for linear elastic materials. Prerequisite: MAE 6040 or instructor's consent. (3 cr) (Sp)

*****MAE 7050. Plasticity.** Analysis of stresses, deformation, and collapse in devices constructed of plastic material. Prerequisite: MAE 6040 or CEE 6080/5080 or instructor's consent. Also taught as CEE 7050. (3 cr) (Sp)

MAE 7080. Advanced Plate and Shell Theory. Analysis of plate and shell structures by classical and numerical methods. Emphasis on numerical solutions. Prerequisite: Instructor's consent. Also taught as CEE 7080. (3 cr) (F)

*****MAE 7350. Intelligent Control Systems.** Intelligent control strategies, including neural network, fuzzy logic, associated memory networks, and rule-based control systems. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as ECE 7350. (3 cr) (F)

*****MAE 7360. Optimal and Robust Control.** Advanced methods of control system analysis and design. Operator approaches to optimal control, including LQR, LQG, and L1 optimization techniques. Robust control theory, including QRT, H-infinity, and interval polynomial approaches. Prerequisite: ECE/MAE 6320 or instructor approval. Also taught as ECE 7360. (3 cr) (Sp)

*****MAE 7380. Advanced Dynamics and Vibrations.** Advanced techniques in dynamics and vibrations. Prerequisite: CEE/MAE 6180. (3 cr) (F)

MAE 7580. Advanced Finite Element Analysis in Fluid Mechanics. Application of the finite element method of analysis to problems in fluid mechanics. Use of higher order element to two- and three-dimensional flows. Prerequisites: CEE 3510, CEE/MAE 6570; or MAE 3420, CEE/MAE 5020. Also taught as CEE 7580. (3 cr) (Sp)

MAE 7930. Special Problems. Independent or group study of engineering problems not covered in regular course offerings. (1-3 cr) (F,Sp,Su) ®

MAE 7970. Dissertation Research. (1-12 cr) (F,Sp,Su) ®

MAE 7990. Continuing Graduate Advisement. (1-12 cr) (F,Sp,Su) ®

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.

*Taught 2002-2003.

**Taught 2003-2004.

***Taught alternate years. For further information, consult department.