MECHANICAL ENGINEERING (MEGN)

MEGN200. INTRODUCTION TO MECHANICAL ENGINEERING: PROGRAMMING AND HARDWARE INTERFACE. 3.0 Semester Hrs.
This course introduces programming skills using Matlab as a means to collect and analyze data and utilizes Arduinos as a platform for prototyping circuits and designs. This course reinforces the engineering design process through problem definition and identifying constraints and criteria, encouraging multiple solutions, and introducing analysis in design through prototyping. Prerequisite: EDNS155 or HNRS105 or HNRS115 or HNRS198, CSCI101, CSCI102.
Course Learning Outcomes

- 1. Demonstrate programming logic through use of Matlab
- 2. Compose software programs (in Arduino) to solve engineering problems
- 3. Demonstrate hardware and software interface
- 4. Use Arduinos to produce a working prototype
- 5. Design simple circuits in use with Arduinos
- 6. Document problem definition, user needs, and project requirements through clear constraints and criteria
- 7. Create a working prototype and validate through testing
- 8. Compute the probability of a data set using MATLAB
- 9. Calculate statistics of a data set using MATLAB
- 10. Demonstrate technical writing and professional documentation of projects
- 11. Verbally communicate design solutions
- 12. Collaborate with team members to solve a design problem and produce a protoytpe.

MEGN201. INTRODUCTION TO MECHANICAL ENGINEERING: DESIGN & FABRICATION. 3.0 Semester Hrs.
(I, II, S) This course reinforces basic drawing skills from Cornerstone Design, introduces SolidWorks tools to advance modeling skills, introduces machine shop skills (including safety and use of mill, lathe and CNC) and introduces GDnT practices important in fabrication and manufacturing, and prob-stats relevant to manufacturing. 3 hours lecture; 3 semester hours. Prerequisite: EDNS151 or EDNS155; HNRS105 or HNRS198A.
Course Learning Outcomes

- 1. Demonstrate basic drawing skills in orthographic views
- 2. Use SolidWorks to design an object and/or product
- 3. Demonstrate good GDnT practice in both documentation and prototypes
- 4. Employ general shop safety skills
- 5. Demonstrate manual use of mill - lathe - CNC
- 6. Apply statistical methods relative to manufacturing and GDnT
- 7. Design (prototype) a part for manufacturability (tolerances, assembly, clearances, etc.)
- 8. Demonstrate ability to implement quality control on designed parts
- 9. Communicate technical information through drawings and letter of intent
- 10. Collaborate with team members to produce a part/product.

MEGN212. INTRODUCTION TO SOLID MECHANICS. 3.0 Semester Hrs.
Equivalent with MEGN312,
This course introduces students to the principles of Solid Mechanics. Upon completion, students will be able to apply Solid Mechanics theories to analyze and design machine elements and structures using isotropic materials. The skills and knowledge learned in this course form the required foundation for Intro to Finite Element Analysis, Advanced Mechanics of Material, Machine Design and other advanced topics in engineering curricula. Practically, it enables students to solve real-world mechanical behavior problems that involve structural materials. This courses places an early focus on ensuring students have mastered the creation of free body diagrams given a mechanical system, then moves on to introduce and reinforce learning of stress and strain transformations, and failure theories. In practicing this knowledge, students will be able to analyze and design machine elements and structures of homogenous and heterogeneous geometries under axial, torsional, bending, transverse shear, internal pressure loads, and non-uniform loads. Students will be able to quantitatively communicate the outcomes. May not also receive credit for CEEN311. Prerequisite: CEEN241 (C- or better).
Course Learning Outcomes

- 1. Use free body diagrams in the analysis of structures
- 2. Apply principles of Solid Mechanics to the analysis of elastic structures under simple, combined, and thermal loading
- 3. Use Mohr’s circle and stress transformation equations
- 4. Use stress elements to show stress state at a point
- 5. Use failure theories to assess safety of design
- 6. Effectively communicate the outcomes of analysis and design problems

MEGN261. THERMODYNAMICS I. 3.0 Semester Hrs.
This course is a comprehensive treatment of thermodynamics from a mechanical engineering point of view. Topics include: Thermodynamic properties of substances inclusive of phase diagrams, equations of state, internal energy, enthalpy, entropy, and ideal gases; principles of conservation of mass and energy for steady-state and transient analyses; First and Second Law of thermodynamics, heat engines, and thermodynamic efficiencies; Application of fundamental principles with an emphasis on refrigeration and power cycles. May not also receive credit for CBEN210. Prerequisite: MATH213 (C- or better).
Course Learning Outcomes

- 1. Identify the boundary of a system by drawing a control surface and label the transfer of mass and energy across the control surface for a given process.
- 2. Apply balance equations (mass, energy, and entropy) to analyze steady and unsteady processes, relating a system’s inputs and outputs (heat, work, and mass transfer) and material properties (temperature, pressure, etc.) with one another.
- 3. Determine the properties of pure substances using equations of state, property tables, software tools, or thermodynamic surfaces, choosing an appropriate method.
- 4. Use the 1st and 2nd law of thermodynamics to identify possible and impossible processes.
- 5. Apply the concept of isentropic efficiency to compare actual and ideal devices.
- 6. Use the concepts of thermal efficiency and coefficient of performance to analyze the performance of power cycles (power plants and internal combustion engines), and assess the performance by comparing to other cycles, to theoretical limits, and to practical material and economic limitations.
- 7. Represent thermodynamic processes in multiple formats, by drawing process schematics, drawing thermodynamic property (P-v and T-s) diagrams, applying balance equations, and writing for diverse audiences (science and non-science).
- 8. Design and analyze thermodynamic systems (cycles and other devices) to meet heating, cooling, and/or power needs for a specified application.

MEGN298. SPECIAL TOPICS. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN299. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN300. INSTRUMENTATION & AUTOMATION. 3.0 Semester Hrs.
This course will explore instrumentation and automation of electro-mechanical systems. Students will utilize LabView and electro-mechanical instrumentation to solve advanced engineering problems. Class activities and projects will highlight the utility of LabView for real-time instrumentation and control. Prerequisite: MEGN200 (C- or better). Corequisite: MEGN201.
Course Learning Outcomes

- 1. Recognize the strengths and limitations of the software and hardware platforms for instrumentation, data collection and analysis
- 2. Create customized instrumentation systems and user interfaces
- 3. Explore software architectures for instrumentation and control
- 4. Explore various sensor and actuator technologies
- 5. Apply probability and statistics in large data sets
- 6. Design an instrumentation system for a specific application
- 7. Communicate testing procedures and analysis in a technical report
- 8. Discuss hardware platforms for embedded industrial instrumentation and control, including NI myRIO and CompactRIO

MEGN301. MECHANICAL INTEGRATION & DESIGN. 3.0 Semester Hrs.
Students will utilize the engineering design process and knowledge in systems level design to produce a mechanical product/process. Students will reverse engineer a product/process to emphasize the steps in the design process. Students will select a longer course project, which is intended to reinforce engineering skills from other courses. The project topics would parallel one of the four research disciplines in ME, and students would be able to choose a topic pathway that emphasizes opportunities for mechanical engineering graduates. Prerequisite: MEGN200 (C- or better), MEGN201 (C- or better), MEGN300 (C- or better). Corequisite: MEGN 381.
Course Learning Outcomes

- 1. apply the engineering design process, from recognition of client needs to release of a fully-tested mechanical/electromechanical product
- 2. apply a systems-level approach in the design of a product
- 3. incorporate regulatory requirements and/or standards and additional realistic constraints pertinent to mechanical/electromechanical devices, products or systems into the design process
- 4. apply technical knowledge in engineering, mathematics, and the sciences to design and benchmark mechanical/electromechanical products
- 5. use modern engineering software tools in mechanical product design (e.g. Matlab, SolidWorks, or LabView)
- 6. demonstrate use of statistics and probability in the analysis of test results
- 7. professionally document and communicate design efforts

MEGN315. DYNAMICS. 3.0 Semester Hrs.

This course will cover particle kinematics (including 2-D motion in x-y coordinates, normal-tangential coordinates, & polar coordinates), rigid body kinematics (Including relative velocities and accelerations), rigid body kinetics (including the equation of motion, work and energy, linear impulse-momentum, & angular momentum), and introduction to vibrations. Prerequisite: CEEN241 (C- or better) and MATH225 (C- or better). MATH225.

Course Learning Outcomes

- 1. Understand the basic principles of particle dynamics.
- 2. Understand the basic principles of planar rigid body dynamics.
- 3. Demonstrate the ability to apply the principles of dynamics to solve basic engineering problems with analytic and numerical techniques.

MEGN324. INTRODUCTION TO FINITE ELEMENT ANALYSIS. 3.0 Semester Hrs.

Equivalent with MEGN424,

This course aims to teach basic proficiency with Finite Element Analysis (FEA), which is the most widely used computer aided engineering tool in industry, academia, and government. Fundamentals of FEA theory are introduced, but the majority of the course is spent learning practical skills with commercial FEA software. Students will work interactively with the instructor and with their peers to complete hands-on FEA examples based primarily on problems in structural mechanics. Applications of FEA for heat conduction, natural frequency analysis, and design optimization are covered briefly. The course will conclude with a mini project on which students use FEA skills for engineering analysis and design. The importance of verification and validation (V&V) for critical evaluation of FEA predictions is emphasized, and students will make frequent use of statics and solid mechanics principles to corroborate their FEA results. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).

Course Learning Outcomes

- Understand the basic concepts of th e global stiffness force-displacement matrix equations in the displacement finite element method.
- Use a commercial finite element software package (SW Simulation), associated CAD modeling software (SolidWorks) and an engineering math softwa re (MATH CAD) to perform engineering analysis.
- Apply classical engineering methods such as statics and mechanics of materials to check whether the results of a finite element analysis are sensible.
- Apply finite element analysis in the engineering design process. For example, design a simple truss structure and perform finite element analyses to determine the dimensions of the structural members based on specified design constraints.
- Write clear and concise technical memoranda and reports describing the results of an engineering analysis and their use in an engineering design if appropriate.

MEGN330. INTRODUCTION TO BIOMECHANICAL ENGINEERING. 3.0 Semester Hrs.

The application of mechanical engineering principles and techniques to the human body presents many unique challenges. The discipline of Biomedical Engineering (more specifically, Biomechanical Engineering) has evolved over the past 50 years to address these challenges. Biomechanical Engineering includes such areas as biomechanics, biomaterials, bioinstrumentation, medical imaging, and rehabilitation. This course is intended to provide an introduction to, and overview of, Biomechanical Engineering and to prepare the student for more advanced Biomechanical coursework. At the end of the semester, students should have a working knowledge of the special considerations necessary to apply various mechanical engineering principles to the human body. Prerequisite: CEEN241.

Course Learning Outcomes

- Understand the basic concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN340. COOPERATIVE EDUCATION. 3.0 Semester Hrs.

(I,II,S) Supervised, full-time engineering- related employment for a continuous six-month period in which specific educational objectives are achieved. Students must meet with the Engineering Division Faculty Co-op Advisor prior to enrolling to clarify the educational objectives for their individual Co-op program. 3 semester hours credit will be granted once toward degree requirements. Credit earned in EGGN340, Cooperative Education, may be used as free elective credit hours or a civil specialty elective if, in the judgment of the Co-op Advisor, the required term paper adequately documents the fact that the work experience entailed high-quality application of engineering principles and practice. Applying the credits as free electives or civil electives requires the student to submit a 'Declaration of Intent to Request Approval to Apply Co-op Credit toward Graduation Requirements' form obtained from the Career Center to the Engineering Division Faculty Co-op Advisor.Prerequisite: Second semester sophomore status and a cumulative grade-point average of at least 2.00.

MEGN351. FLUID MECHANICS. 3.0 Semester Hrs.
This course will cover principles of fluid properties, fluid statics, control-volume analysis, Bernoulli equation, differential analysis and Navier-Stokes equations, dimensional analysis, internal flow, external flow, open-channel flow, and turbomachinery. May not also receive credit for CEEN310 or PEGN251. Prerequisite: CEEN241 with a grade of C- or better or MNGN317 with a grade of C- or better.
Course Learning Outcomes

- Solve mass conservation, momentum, and energy equations for steady-state fluid-flow systems (control-volume analyses).
- Apply differential conservation-of-mass and linear-momentum equations and material derivatives to the solution of flow problems (differential analysis).
- Establish non-dimensional groupings of fluid properties, and apply them in the design of experiments that scale between models and prototypes (dimensional analysis).
- Model fully developed laminar and turbulent pipe flow systems (internal flow).
- Develop the relationships for lift and drag on bodies moving through a fluid (external flow).
- Convey understanding of course materials through homework assignments and exams.
- Distinguish what physical aspects are most critical and have greatest impact on a given problem and design.
- Establish an intuition of fluid behavior, analyze its effects in a given problem, and apply your knowledge to propose design solutions.

MEGN381. MANUFACTURING PROCESSES. 3.0 Semester Hrs.
Equivalent with MEGN380,
Manufacturing Processes is a survey course, that introduces a wide variety of traditional and advanced manufacturing processes with emphasis on process selection and hands-on experiences. Students are expected to have basic knowledge in material science, basic machining and GD&T before entering the class. Throughout the course students analyze the relationships between material properties, process variables and product functionality. Students design and evaluate processes for identifying value while eliminating waste using learned skill-sets including lean methodologies, six-sigma and statistical process control. Quality, cost, standards and ethics related to manufacturing are discussed throughout the semester. Prerequisite: MEGN201 with a grade of C- or better and MTGN202. MEGN212.
Course Learning Outcomes

- Understand basic manufacturing processes and how they apply to designed parts, materials and assemblies
- Be able to use design for manufacturability concepts when designing parts

MEGN385. INTRODUCTION TO CNC AND CAM PROGRAMMING. 1.0 Semester Hr.
This course will guide students through the process of machining parts on a 3-axis CNC (computer numeric-controlled) milling machine. The code for the CNCs will be generated with a CAM (computer aided-machining) program. We will machine parts with multiple setups and discuss strategies for complicated parts. Prerequisite: MEGN 201.
Course Learning Outcomes

- 1. Utilize CAM programming to create the machine code for CNCs.
- 2. Apply milling tool datasheets to optimize the machining performance.
- 3. Select tooling based on the characteristics of specific tools and material setups for creating unique part features.
- 4. Evaluate and select tool operations for efficient material removal and precisely detailed part features.
- 5. Set up and operate 3 axis vertical CNC milling machines
- 6. Design parts for CNC manufacturability
- 7. Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.

MEGN391. INTRODUCTION TO AUTOMOTIVE DESIGN. 3.0 Semester Hrs.
Automotive engineering involves the design and implementation of complex systems. This course introduces students to the workings of the automotive industry, including its history, future, and the stakeholders that determine its direction. The course also covers the major vehicle subsystems and their functionality, interfaces, components, and recent advancements. Students will apply theoretical and practical systems engineering principles to perform a design of a vehicle subsystem to gain perspective of how the automotive design process is executed and how it fits into the larger scope of the automotive industry. Prerequisite: MEGN200 with of grade C- or better.
Course Learning Outcomes

- 1. Work on a successful design team to create a design for a significant mechanical, electrical, structural, or industrial system.
- 2. Identify performance, manufacturing, and safety standards, on system and subsystem levels, that will lead to design success.
- 3. Create design concepts and alternatives, and apply selection criteria.
- 4. Identify and solve design-related engineering analysis problems.
- 5. Conduct cost and safety analyses.
- 6. Communicate a design process and its results by written report, technical illustration, and oral presentation.
- 7. Manage a design project, including: making and keeping schedules; allocating and utilizing resources; specifying and acquiring components; meeting budgets and deadlines.

MEGN398. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN399. INDEPENDENT STUDY. 1-6 Semester Hr.
(I, II) Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MEGN408. INTRODUCTION TO SPACE EXPLORATION. 3.0 Semester Hrs.
Overview of extraterrestrial applications of science and engineering by covering all facets of human and robotic space exploration, including its history, current status, and future opportunities in the aerospace and planetary science fields. Subtopics include: the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), current research, missions, and projects, the international and commercial perspectives, and discussion of potential career opportunities. This seminar style class is taught by CSM faculty, engineers and scientists from space agencies and research organizations, aerospace industry experts, and visionaries and entrepreneurs of the private space commerce sector.

MEGN412. ADVANCED MECHANICS OF MATERIALS. 3.0 Semester Hrs.
This Advanced Mechanics of Materials course builds upon the learning outcomes of the pre-requisite Mechanics of Materials (Solid Mechanics) course to teach students the fundamentals of elastic deformations. Introduction to energy methods, strain and stress transformations, constitutive relations for isotropic and orthotropic materials, and to fracture mechanics is realized through theory development, application examples, and numerical solutions. Knowledge from this course will enable students to work on variety of engineering applications in Mechanical, Materials, Aerospace, Civil and related engineering fields. Prerequisite: MEGN212 (C- or better) or CEEN311 (C- or better).
Course Learning Outcomes

- 1. Define, and apply, displacement-strain relationships. Calculate principal strains, maximum shear strain in 2D and 3D.
- 2. Use gauges and rosettes for strain measurements.
- 3. Find stresses at a point, principal stresses and max shear stress.
- 4. Define, and apply, the generalized form of Hooke’s Law for isotropic materials.
- 5. Define, and apply, the generalized form of Hooke’s Law for orthotropic materials.
- 6. Apply theories of failure for ductile and brittle materials.
- 7. Use energy methods to compute strain energy, determine the effect of impact loading, determine displacements due to single or multiple loads, and solve statically indeterminate problems.
- 8. Define crack modes and stress intensity factor. Estimate stresses in the “near-field”.
- 9. Apply plastics zone size correction to the crack length.
- 10. Explain, and apply, the design philosophy given by the relationship between material property (fracture toughness), design stress, allowable flow size or NDT flaw detection.
- 11. Estimate fatigue life of cracked and un-cracked components.

MEGN414. MECHANICS OF COMPOSITE MATERIALS. 3.0 Semester Hrs.
Introductory course on the mechanics of fiber-reinforced composite materials. The focus of the course is on the determination of stress and strain in a fiber-reinforced composite material with an emphasis on analysis, design, failure by strength-based criteria, and fracture of composites. Anisotropic materials are discussed from a general perspective then the theory is specialized to the analysis of fiber-reinforced materials. Both thermal and hygroscopic sources of strain are introduced. Classical laminated plate theory is next developed, and design of laminated composite structures is introduced. The analysis of helically reinforced composite tubes concludes the course. Prerequisite: MEGN212 (C- or better).
Course Learning Outcomes

- 1. Apply concepts of the mechanics of composite materials to the analysis of fiber-reinforced lamina
- 2. Use transformation equations to analyze fiber-reinforced lamina with arbitrary fiber orientation
- 3. Predict overall elastic properties of a fiber-reinforced lamina from micromechanics models
- 4. Choose and apply an appropriate failure criterion to assess safety of fiber-reinforced lamina
- 5. Apply classical laminated plate theory to calculate stresses in laminated composites
- 6. Design a laminated plate structure given mechanical and thermal loads
- 7. Determine the stress state in helically reinforced composite tubes

MEGN416. ENGINEERING VIBRATION. 3.0 Semester Hrs.
This course introduces linear theory of mechanical vibrations as applied to single- and multi-degree-of-freedom systems. Specifically, students learn to analyze and measure free and forced vibrations of spring-mass-damper systems in response to different types of loading including harmonic, impulse, and general transient loading. Force balance and energy methods are introduced as means to create models of vibrating mechanical components. Ultimately, students learn to apply these theories to design vibration isolators and dampers for machines subject to translational and rotational vibrations, including machines with rotating unbalances and two or more vibrating masses. Prerequisite: MEGN315 (C- or better).
Course Learning Outcomes

- ability to apply knowledge of mathematics, science, and engineering
- ability to identify, formulate, and solve engineering problems

MEGN417. VEHICLE DYNAMICS & POWERTRAIN SYSTEMS. 3.0 Semester Hrs.

This course offers an introduction to automotive engineering with a focus on vehicle design, suspension, powertrain and aerodynamics. The course is designed to introduce students to both theoretical and practical concepts of vehicle design with applications in increasing fuel efficiency and vehicle performance. The study of automotive engineering is of increasing importance as new technologies emerge and advances continue to be made to existing designs to create the ultimate driving experience; while having minimal impact on the environment by reducing tailpipe gas emissions, noise pollution, and waste material during manufacturing of new vehicles. Prerequisite: MEGN315, MEGN324, MEGN261.

Course Learning Outcomes

- Students will use fundamental lateral and longitudinal dynamic equations to design the proper suspension setup for various road and racing scenarios
- Students will be able to identify key components of a vehicle's suspension and powertrain system and describe their respective function to the performance of the vehicle
- Students will perform relevant calculations and numerical modeling related to vehicle design and handling characteristics (e.g. roll, over/under-steer)
- Students will solve basic engine performance calculations related to power and torque and determine which final drive ratio is adequate for certain racing applications

MEGN430. MUSCULOSKELETAL BIOMECHANICS. 3.0 Semester Hrs.

(II) This course is intended to provide mechanical engineering students with a second course in musculoskeletal biomechanics. At the end of the semester, students should have in-depth knowledge and understanding necessary to apply mechanical engineering principles such as statics, dynamics, and mechanics of materials to the human body. The course will focus on the biomechanics of injury since understanding injury will require developing an understanding of normal biomechanics. 3 hours lecture; 3 semester hours. Prerequisite: MEGN212 OR CEEN311; MEGN315; MEGN330 (C- or better).

Course Learning Outcomes

- Understand advanced concepts in applying material learned in other Mechanical Engineering classes (statics, mechanics of materials) to analysis of the human body

MEGN435. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.

Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties, interactions with the environment, and computational optimization to construct detailed computer models and simulations of human movement. Prerequisite: MEGN315 with a grade C- or better, MEGN330 with grade of C- or better.

MEGN441. INTRODUCTION TO ROBOTICS. 3.0 Semester Hrs.

(I, II) Overview and introduction to the science and engineering of intelligent mobile robotics and robotic manipulators. Covers guidance and force sensing, perception of the environment around a mobile vehicle, reasoning about the environment to identify obstacles and guidance path features and adaptively controlling and monitoring the vehicle health. A lesser emphasis is placed on robot manipulator kinematics, dynamics, and force and tactile sensing. Surveys manipulator and intelligent mobile robotics research and development. Introduces principles and concepts of guidance, position, and force sensing; vision data processing; basic path and trajectory planning algorithms; and force and position control. EENG307 is recommended to be completed before this course. 2 hours lecture; 3 hours lab; 3 semester hours. Prerequisite: (MEGN200 or CSCI261 or CSCI200) and (EENG281 or EENG282 or PHGN215).

Course Learning Outcomes

- To be completed at a later time (course coordinator on leave)

MEGN451. AERODYNAMICS. 3.0 Semester Hrs.

Review of elementary fluid mechanics and engineering; Two-dimensional external flows, boundary layers, and flow separation; Gas dynamics and compressible flow: Isentropic flow, normal and oblique shocks, rocket propulsion, Prandtl-Meyer expansion fans; Application of computational fluid dynamics. Prerequisite: MEGN351(C- or better).

Course Learning Outcomes

- • Apply control-volume conservation-of-mass, linear-momentum, angular-momentum and energy equations to the solution of flow problems.
- • Apply differential conservation-of-mass and linear-momentum equations and to the solution of flow problems.
- • Understand development and analysis of boundary layers.
- • Comprehend analysis of compressible and supersonic flows, including shock waves.
- • Understand theory and application of turbomachinery.

MEGN452. INTRO TO SPACE EXPLORATION AND RESOURCES. 3.0 Semester Hrs.

Overview of human and robotic space exploration, including its history, current status, and future opportunities. Course topics cover the space environment, space transportation systems, destinations (Low-Earth orbit, Moon, Mars, asteroids, other planets), the aerospace industry, space commerce and law, and the international space activity. Emphasis is placed on the field of space resources, including their identification, extraction, and utilization to enable future space exploration and the new space economy.

MEGN453. AEROSPACE STRUCTURES. 3.0 Semester Hrs.
This course covers advanced mechanics of materials relevant to the analysis and design of aerospace structures. Focused topics include multiaxial stress states, nonsymmetric loading, composites, airframe loads, and shear flow emphasizing lightweight, often thin-walled structures common in aerospace applications. Other advanced topics will be introduced, time permitting. Prerequisite: MEGN212.
Course Learning Outcomes

- Understand physical & mathematical relationship(s) between displacement, stress, and strain.
- Apply concepts of compatibility, equilibrium, and constitutive relations on geometries preva- lent in aerospace structural analysis.
- Distinguish appropriate failure criteria and assumptions under various airframe loading con- ditions.
- Solve basic boundary value problems on plane stress, plane strain, torsion, beam bending, and shear flow for thin-walled structures.
- Gain team experience through a design/build/test project that utilizes concepts learned in the course

MEGN454. ORBITAL MECHANICS. 3.0 Semester Hrs.
Orbital Mechanics introduces students to the dynamics that govern motion of bodies in space and the utilization of these dynamics in spacecraft orbit and trajectory design. This course develops the mathematical foundation of propagating, describing, and manipulating the motion of a spacecraft in orbit. Throughout the semester students will script their own (basic) universe simulators to examine the various forces and geometries in orbit. Prerequisite: MEGN315.
Course Learning Outcomes

- 1. Calculate the position of a body (satellite) under Keplerian dynamics as a function of time.
- 2. Interpret the state and orbit type of a body (satellite) in an elliptical orbit using classic orbital elements.
- 3. Implement a state propagator for a body (satellite) in an elliptical orbit in Keplerian dynamics and under common perturbation models.
- 4. Calculate the impulsive delta-V maneuvers required to manipulate a body's (satellite) orbit state in common transfers

MEGN455. AEROSPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
An introduction to aerospace systems engineering. This course is designed for students to explore both theoretical and practical systems engineering concepts and knowledge using examples drawn from the aerospace and defense industries. Starting with the systems engineering v model, students will gain hands on experience working with modern Model Based Systems Engineering (MBSE) software and develop systems engineering deliverables such as Concepts of Operations (ConOps) documents as part of a semester long project. Prerequisite: Best taken just before Senior Design or as a co-req with Senior Design I.
Course Learning Outcomes

- 1. Students will be able to describe the most important systems engineering standards and best practices as well as newly emerging approaches using the systems engineering V-model.
- 2. Students will be able to write and decompose multi-level system requirements
- 3. Students will learn applied model-based systems engineering and demonstrate their understanding using an industry standard Model Based System Engineering (MBSE) software
- 4. Students will develop and demonstrate applied model-based engineering, through development of support document for their semester long project
- 5. Students will demonstrate their understanding of system mission and operating environments through the develop of a concept of operations (ConOps) document
- 6. Students will be able to identify system risks and opportunities and appropriately rank and defend their approach
- 7. Students will demonstrate their understanding of interfaces, constraints, and system specifications/figures of merit/technical performance metrics/measure of performance through the drafting of an Interface Control Document (ICD)
- 8. Students will visually communicate their understanding of project execution via the develop of a system engineering management plan (SEMP)
- 9. Students will demonstrate understanding of the value of appropriate test procedures and test plans through the development of a project test plan
- 10. Students will be able to differentiate between validation and verification in the systems engineering context

MEGN456. SPACE OPERATIONS AND MISSION DESIGN. 3.0 Semester Hrs.

Space Operations and Mission Design (SOMD) is a course for upper level undergraduate and graduate students at Mines who are interested in expanding their knowledge of astrodynamics, spacecraft and space mission design, project management, and systems engineering.
Upon leaving the course, students will have a head start on potential internships/careers in the aerospace industry armed with key vocabulary and terms, experience with industry relevant software and tools, and core skills and knowledge gained through practice addressing real-world problems in the space domain.

Course Learning Outcomes

- Students shall develop and defend their mission risk/opportunity assessment, applying risk matrices and mitigation plans as tools.
- Students shall collaboratively define, design, and plan a simulated mission considering stakeholders, associated space laws/regulations, and resource management.
- Students shall develop and assess technical resource budgets. Examples include: mass, power, thermal, telecommunications, and data volume.
- Students shall apply appropriate terminology associated with space flight operations
- Students shall execute space mission planning principles such as: Orbit determination, Orbital maneuvering, Launch windows, Orbital rendezvous, and Proximity operations
- Students shall analyze orbital motion by visualizing from both inertial and relative perspectives
- Students shall synthesize the effects of launch, orbital maneuvers, rendezvous, and proximity operations on space situational awareness and space mission design and operations

MEGN461. THERMODYNAMICS II. 3.0 Semester Hrs.

This course extends the subject matter of Thermodynamics I (MEGN261) to include the study of exergy, ideal gas mixture properties, psychrometrics and humid air processes, chemical reactions, and the 1st, 2nd and 3rd Laws of Thermodynamics as applied to reacting systems. Chemical equilibrium of multi-component systems, and simultaneous chemical reactions of real combustion and reaction processes are studied. Concepts of the above are explored through the analysis of advanced thermodynamic systems. 3 hours lecture; 3 semester hours. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better).

Course Learning Outcomes

- Ability to solve and analyze physical processes that include: Exergy (2nd Law) analysis of energy systems • Mixtures of ideals gases • Psychrometrics including mass and energy balances of humid air processes • Chemical reactions, combustion, and fuel/air stoichiometry • Phase and chemical equilibrium • Simultaneous reactions and Ionization • Thermodynamics of compressible flow in nozzles including shock • Advanced thermodynamic cycles including cascaded and absorption refrigeration systems, cryogenics, and gas turbine and combined cycles.

MEGN465. ELECTRIC VEHICLE POWERTRAIN SYSTEMS. 3.0 Semester Hrs.

In the fast-evolving world of sustainable transportation, it is essential for engineers in the automotive industry to understand energy conversion, storage, utilization, and optimization of vehicle powertrains. Electric Vehicle Powertrain Systems (EVPS) is designed to provide students with a comprehensive understanding of the essential powertrain components in battery-electric vehicles (BEVs) including motors, controllers, and battery packs. Through a combination of theoretical modeling and hands-on projects, students will gain knowledge and skills in powertrain system design to achieve vehicle objectives, encompassing energy analysis, power requirements, and efficiency considerations. The course will also explore the state-of-the-art in safety measures, management strategies, control systems, charging/balancing techniques, and State of Charge (SOC)/State of Health (SOH) estimation for EV battery packs. Prerequisite: MEGN300 or EEGN 282.

Course Learning Outcomes

- 1. Articulate the functions and interrelationships of the core powertrain components in electric vehicles, including the motor, controller, and battery pack
- 2. Design a vehicle powertrain architecture and select powertrain components that meet the overarching goals of an electric vehicle, incorporating top-level requirements such as energy use, power output, and efficiency optimization
- 3. Explain the operating principles and fundamental characteristics of Li-ion batteries using underlying electrochemical processes and implement them in an equivalent circuit battery cell model
- 4. Apply experimental methods used to characterize the performance of Li-ion cells in automotive applications, while elucidating the principles and significance of these techniques in assessing battery behavior and performance.
- 5. Critically assess and compare the state of the art in safety protocols, management strategies, control systems, and charging/balancing techniques for battery packs in electric vehicle powertrain systems.
- 6. Devise a functional design for a battery pack tailored to the specific requirements and constraints of a full-size electric vehicle, integrating considerations such as energy storage capacity, thermal management, safety measures, and space utilization

MEGN466. INTRODUCTION TO INTERNAL COMBUSTION ENGINES. 3.0 Semester Hrs.

Introduction to Internal Combustion Engines (ICEs); with a specific focus on Compression Ignition (CI) and Spark Ignition (SI) reciprocating engines. This is an applied thermo science course designed to introduce students to the fundamentals of both 4-stroke and 2-stroke reciprocating engines ranging in size from model airplane engines to large cargo ship engines. Course is designed as a one-semester course for students without prior experience with IC engines, however, the course will also include advanced engine technologies designed to deliver more horsepower, utilize less fuel, and meet stringent emission regulations. Discussion of advancements in alternative fueled engines will be covered as well. This course also includes an engine laboratory designed to provide hands-on experience and provide further insight into the material covered in the lectures. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better. Co-requisite: MEGN471.

Course Learning Outcomes

- ABET j and k outcomes will be measured through homework assignments and projects.

MEGN467. PRINCIPLES OF BUILDING SCIENCE. 3.0 Semester Hrs.
This course covers the fundamentals of building heating, ventilation, and air conditioning (HVAC) systems and the use of numerical heat and moisture transfer models to analyze or design different building envelope and HVAC systems. Prerequisite: MEGN351 with a grade of C- or better, MEGN261 with a grade of C- or better.
Course Learning Outcomes

- 1. Understand and apply fundamental principles to HVAC design
- 2. Describe components in HVAC systems
- 3. Understand how building HVAC loads are calculated and calculate building HVAC loads
- 4. Conduct building energy analyses using computer simulation tools

MEGN469. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.
Equivalent with CBEN469,MTGN469,
Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. Prerequisite: MEGN261 with a grade of C- or better or CBEN357 with a grade of C- or better.

MEGN471. HEAT TRANSFER. 3.0 Semester Hrs.
(I, II) Engineering approach to conduction, convection, and radiation, including steadystate conduction, nonsteady-state conduction, internal heat generation conduction in one, two, and three dimensions, and combined conduction and convection. Free and forced convection including laminar and turbulent flow, internal and external flow. Radiation of black and grey surfaces, shape factors and electrical equivalence. Prerequisite: MEGN351 (C- or better), MEGN261 (C- or better), and MATH307. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Outcome 1: Ability to analyze and design heat transfer processes and systems
- Outcome 2: Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice"

MEGN475. INTRODUCTION TO NUCLEAR ENGINEERING. 3.0 Semester Hrs.
An overview of major concepts and themes of nuclear engineering founded on the fundamental properties of the neutron, and emphasizing the nuclear physics bases of nuclear reactor design and its relationship to nuclear engineering problems. Major topics that introduce fundamental concepts in nuclear engineering include the physics and chemistry of radioactive decay, radiation detection, neutron physics, heat transfer in nuclear reactors, and health physics. Nuclear engineering topics relevant to current events are also introduced including nuclear weapons, nuclear proliferation, and nuclear medicine. Prerequisite: MATH225, PHGN200.
Course Learning Outcomes

- 1) Apply concepts of radioactivity to solve problems
- 2) Relate neutron production and consumption to aspects of the lifecycle of the nuclear fuel and nuclear power production
- 3) Apply the basics of nuclear reactor physics and heat transfer to reactor design and operation
- 4) Understand the biological effects of radiation and use basic radiation shielding equations

MEGN479. OPTIMIZATION MODELS IN MANUFACTURING. 3.0 Semester Hrs.
We address the mathematical formulation and solution of optimization models relevant in manufacturing operations. The types of deterministic optimization models examined include: (i) network models; (ii) linear programs; (iii) integer programs; and, (iv) nonlinear programs. Application areas include scheduling, blending, equipment replacement, logistics and transportation, among other topics. Students learn not only how to mathematically formulate the models, but also how to solve them with a state-of-the-art modeling language (Ampl) and appropriate solver (e.g., Cplex or Minos). Algorithms for each problem class will be briefly discussed.

MEGN481. MACHINE DESIGN. 3.0 Semester Hrs.
(I, II) In this course, students develop their knowledge of machine components and materials for the purpose of effective and efficient mechanical design. Emphasis is placed on developing analytical methods and tools that aid the decision making process. The course focuses on determination of stress, strain, and deflection for static, static multiaxial, impact, dynamic, and dynamic multiaxial loading. Students will learn about fatigue failure in mechanical design and calculate how long mechanical components are expected to last. Specific machine components covered include shafts, springs, gears, fasteners, and bearings. 3 hours lecture; 3 semester hours. Prerequisite: MEGN315 (C- or better) or PHGN350 (C- or better), and MEGN324 (C- or better).
Course Learning Outcomes

- 1. Use a systematic approach for solving design problems
- 2. Be able to design new systems for current technology

MEGN485. MANUFACTURING OPTIMIZATION WITH NETWORK MODELS. 3.0 Semester Hrs.
Equivalent with EBGN456,
(I) We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. 3 hours lecture; 3 semester hours. Prerequisite: MATH111, MATH 112.
Course Learning Outcomes

- Mathematically formulate optimization models to reflect real-world manufacturing settings.
- Study algorithms and software to solve associated optimization problems.
- Use skills from other engineering courses to identify manufacutring problems and set them up as optimization models.

MEGN486. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
This course addresses the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. Prerequisite: MATH332 or EBGN509.
Course Learning Outcomes

- 1. Understand how to formulate linear optimization models.
- 2. Understand how to solve linear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear optimization models and how this affects their ability to be solved.
- 4. Understand sensitivity and post-optimality analysis.

MEGN487. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN587,
This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate nonlinear optimization models.
- 2. Understand how to solve nonlinear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying nonlinear optimization models and how this affects their ability to be solved.

MEGN488. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN588,
(I) This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate linear-integer optimization models.
- 2. Understand how to solve linear-integer optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear-integer optimization models and how this affects their ability to be solved.
- 4. Understand decomposition techniques to aid in solution.

MEGN498. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 1-6 Semester Hr.
(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MEGN499. INDEPENDENT STUDY. 1-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, when a student and instructor agree on a subject matter, content, and credit hours. Note that MEGN499 does not count as an MEGN Teachnical Elective, though the course does count as a Free Elective. Prerequisite: Independent Study form must be completed and submitted to the Registrar.

MEGN501. ADVANCED ENGINEERING MEASUREMENTS. 3.0 Semester Hrs.
Equivalent with EGGN501,
Introduction to the fundamentals of measurements within the context of engineering systems. Topics that are covered include: errors and error analysis, modeling of measurement systems, basic electronics, noise and noise reduction, and data acquisition systems. Prerequisite: EGGN250, EENG281 or equivalent, and MATH201 or equivalent, Graduate student status.

MEGN502. ADVANCED ENGINEERING ANALYSIS. 3.0 Semester Hrs.
(I) Introduce advanced mathematical and numerical methods used to solve engineering problems. Analytic methods include series solutions, special functions, Sturm-Liouville theory, separation of variables, and integral transforms. Numerical methods for initial and boundary value problems include boundary, domain, and mixed methods, finite difference approaches for elliptic, parabolic, and hyperbolic equations, Crank-Nicolson methods, and strategies for nonlinear problems. The approaches are applied to solve typical engineering problems. The student must have a solid understanding of linear algebra, calculus, ordinary differential equations, and Fourier theory. 3 hours lecture.

MEGN503. GRADUATE SEMINAR. 0.0 Semester Hrs.
(I, II) This is a seminar forum for graduate students to present their research projects, critique others? presentations, understand the breadth of engineering projects both within their specialty area and across the Division, hear from leaders of industry about contemporary engineering as well as socio-economical and marketing issues facing today?s competitive global environment. In order to improve communication skills, each student is required to present a seminar in this course before his/her graduation from the Mechanical Engineering graduate program. Prerequisite: Graduate standing. 1 hour per week; 0 semester hours. Course is repeatable, but no coursework credit is awarded.

MEGN510. THEORY OF ELASTICITY. 3.0 Semester Hrs.
This is a graduate course that builds upon the learning outcomes of Continuum Mechanics course to introduce students the fundamentals of Theory of Elasticity. Introduction is realized through theory development, application examples, and numerical solutions. Learning outcomes from this course would be essential to further studies in visco-elasticity and plasticity. Knowledge from this course will enable students to work on variety of engineering applications in Mechanical, Materials, Aerospace, Civil and related engineering fields. This course is cross-listed with MLGN517.
Course Learning Outcomes

- 1. Recall definitions for indicial notation, transformation rules for tensors, and eigenvalue problems. Tensor algebra and tensor calculus.
- 2. Define, and apply, displacement-strain relationships. Strain measurements using strain gauges and rosettes. Calculate principal strains, maximum shear strain in 3D.
- 3. Establish the definitions, and use, stress tensor, traction vector, normal, and shear tractions. Find stresses at a point on a given plane, principal stresses and max shear stress.
- 4. State the general three-dimensional constitutive law for linear elastic materials. Define material symmetry and the engineering notation stiffness matrix for materials with monoclinic, orthotropic, transversely isotropic, cubic symmetry.
- 5. Define, and apply, the generalized form of Hooke’s Law for isotropic materials.
- 6. State, and apply, the field equations for linear isotropic elasticity.
- 7. Write clear and complete boundary condition statement.
- 8. Use the semi-inverse method to find solutions for two dimensional elasticity problems.
- 9. Use the Airy stress function to find solutions for two dimensional elasticity problems.
- 10. Define, and apply, yield theories (von Mises and Tresca) for isotropic solids.
- 11. Use the Prandtl stress function to find solutions for torsional elasticity problems.

MEGN511. FATIGUE AND FRACTURE. 3.0 Semester Hrs.
Equivalent with MTGN545,
(I) Basic fracture mechanics as applied to engineering materials, S-N curves, the Goodman diagram, stress concentrations, residual stress effects, effect of material properties on mechanisms of crack propagation. Fall semesters, odd numbered years.

MEGN512. ADVANCED ENGINEERING VIBRATION. 3.0 Semester Hrs.
Vibration theory as applied to single- and multi-degree-of freedom systems. Free and forced vibrations to different types of loading-harmonic, impulse, periodic and general. Natural frequencies. Role of Damping. Importance of resonance. Modal superposition method. Prerequisite: MEGN315, 3 hours lecture; 3 semester hours.

MEGN513. KINETIC PHENOMENA IN MATERIALS. 3.0 Semester Hrs.
Equivalent with MLGN511,
Linear irreversible thermodynamics, dorce-flux couplings, diffusion, crystalline materials, amorphous materials, defect kinetics in crystalline materials, interface kinetics, morphological evolution of interfaces, nucleation theory, crystal growth, coarsening phenomena and grain growth, solidification, spinodal decomposition. Prerequisites: MATH225: Differential equations (or equivalent), MTGN555/CBEN509: Thermodynamics (or its equivalent).

MEGN514. CONTINUUM MECHANICS. 3.0 Semester Hrs.
(I) This is a graduate course covering fundamentals of continuum mechanics and constitutive modeling. The goal of the course is to provide graduate students interested in fluid and solid mechanics with the foundation necessary to review and write papers in the field. Students will also gain experience interpreting, formulating, deriving, and implementing three-dimensional constitutive laws. The course explores six subjects: 1. Mathematical Preliminaries of Continuum Mechanics (Vectors, Tensors, Indicial Notation, Tensor Properties and Operations, Coordinate Transformations) 2. Stress (Traction, Invariants, Principal Values) 3. Motion and Deformation (Deformation Rates, Geometric Measures, Strain Tensors, Linearized Displacement Gradients) 4. Balance Laws (Conservation of Mass, Momentum, Energy) 5. Ideal Constitutive Relations (Frictionless & Linearly Viscous Fluids, Elasticity) 6. Constitutive Modeling (Formulation, Derivation, Implementation, Programming). 3 hours lecture, 3 semester hours.
Course Learning Outcomes

- Students will learn vector calculus and index notation by solving problems sets and writing their own Matlab toolboxes of vector calculus operators
- Students will learn general formulations of stress, strain, motion and balance laws by solving problem sets
- Students will be introduced to constitutive modeling for both fluids and solids by solving problem sets and coding a model of their choice for the final project

MEGN515. COMPUTATIONAL MECHANICS. 3.0 Semester Hrs.
(I) A graduate course in computational mechanics with an emphasis on a studying the major numerical techniques used to solve problems that arise in mechanics and some related topical areas. Variational methods are applied throughout as a general approach in the development of many of these computational techniques. A wide range of problems are addressed in one- and two- dimensions which include linear and nonlinear elastic and elastoplastic steady state mechanics problems. Computational algorithms for time dependent problems such as transient dynamics and viscoplasticity are also addressed. In the latter part of the course an introduction to computational methods employing boundary integral equations, and particle methods for solving the mechanical behavior of multi-body systems are also given. Note all the software used in this course is written in MATLAB which has become a widely acceptable engineering programming tool. 3 lecture hours, 3 semester hours. Prerequisite: MEGN502.
Course Learning Outcomes

- Understand and apply the variational approach to governing equations in the development of finite element algorithms.
- Develop, implement and apply computational algorithms to solve linear and nonlinear steady problems.
- Develop, implement and apply computational algorithms to solve transient problems.
- Perform extensive computer coding in MATLAB to develop and modify existing computational mechanics algorithms.

MEGN517. NONLINEAR MATERIAL BEHAVIOR. 3.0 Semester Hrs.
This course provides students with a foundational knowledge in the mechanics of solid materials displaying nonlinear deformation behavior. The course introduces general measures of deformation, such as deformation tensors, velocity gradients, stretch rate and spin tensors, as well as measures of stress, including Cauchy, Green, nominal and material stress. These concepts create a foundation on which are built in-depth descriptions of hypoelastic, hyperelastic, and viscoelastic materials, as well as plastic and viscoplastic material behaviors. For each material behavior addressed, students will put relevant mechanics theory into practice by solving problems from contemporary applications (e.g., additive manufacturing, biomechanics, battery mechanics, aerospace). A working knowledge of continuum mechanics or elasticity theory would be helpful but is not required.
Course Learning Outcomes

- Upon completion of this course, students will have the knowledge to

MEGN520. BOUNDARY ELEMENT METHODS. 3.0 Semester Hrs.
(II) Development of the fundamental theory of the boundary element method with applications in elasticity, heat transfer, diffusion, and wave propagation. Derivation of indirect and direct boundary integral equations. Introduction to other Green?s function based methods of analysis. Computational experiments in primarily two dimensions. Prerequisite: MEGN502. 3 hours lecture; 3 semester hours Spring Semester, odd numbered years.

MEGN521. INTRODUCTION TO DISCRETE ELEMENT METHODS (DEMS). 3.0 Semester Hrs.
(I) Review of particle/rigid body dynamics, numerical DEM solution of equations of motion for a system of particles/rigid bodies, linear and nonlinear contact and impact laws dynamics, applications of DEM in mechanical engineering, materials processing and geo-mechanics. Prerequisites: CEEN311, MEGN315 and some scientific programming experience in C/C++ or Fortran. 3 hours lecture; 3 semester hours Spring semester of even numbered years.

MEGN531. PROSTHETIC AND IMPLANT ENGINEERING. 3.0 Semester Hrs.
Prosthetics and implants for the musculoskeletal and other systems of the human body are becoming increasingly sophisticated. From simple joint replacements to myoelectric limb replacements and functional electrical stimulation, the engineering opportunities continue to expand. This course builds on musculoskeletal biomechanics and other BELS courses to provide engineering students with an introduction to prosthetics and implants for the musculoskeletal system. At the end of the semester, students should have a working knowledge of the challenges and special considerations necessary to apply engineering principles to augmentation or replacement in the musculoskeletal system. Prerequisite: MEGN430.

MEGN532. EXPERIMENTAL METHODS IN BIOMECHANICS. 3.0 Semester Hrs.
(I) Introduction to experimental methods in biomechanical research. Topics include experimental design, hypothesis testing, motion capture, kinematic models, ground reaction force data collection, electromyography, inverse dynamics calculations, and applications. Strong emphasis on hands-on data collection and technical presentation of results. The course will culminate in individual projects combining multiple experimental measurement techniques. Prerequisite: Graduate Student Standing. 3 hours lecture; 3.0 semester hours.

MEGN535. MODELING AND SIMULATION OF HUMAN MOVEMENT. 3.0 Semester Hrs.
Introduction to modeling and simulation in biomechanics. The course includes a synthesis of musculoskeletal properties, interactions with the environment, and computational optimization to construct detailed computer models and simulations of human movement. Prerequisite: MEGN315 and MEGN330.

MEGN536. COMPUTATIONAL BIOMECHANICS. 3.0 Semester Hrs.
Computational Biomechanics provides an introduction to the application of computer simulation to solve fundamental problems in biomechanics and bioengineering. Musculoskeletal biomechanics, joint kinematics, medical image reconstruction, hard and soft tissue modeling, and medical device design are considered in the context of a semester-long project to develop and evaluate an artificial knee implant. Leading commercial software tools are introduced with hands-on exercises. An emphasis is placed on understanding the limitations of the computer model as a predictive tool and the need for rigorous verification and validation of all modeling tasks. Clinical application of biomechanical modeling tools is highlighted and impact on patient quality of life is discussed. Prerequisite: MEGN330, MEGN324.

MEGN537. PROBABILISTIC BIOMECHANICS. 3.0 Semester Hrs.
The course introduces the application of probabilistic analysis methods in biomechanical systems. All real engineering systems, and especially human systems, contain inherent uncertainty due to normal variations in dimensional parameters, material properties, motion profiles, and loading conditions. The purpose of this course is to examine methods for including these sources of variation in biomechanical computations. Concepts of basic probability will be reviewed and applied in the context of engineering reliability analysis. Probabilistic analysis methods will be introduced and examples specifically pertaining to musculoskeletal biomechanics will be studied. Prerequisite: MEGN436 or MEGN536.

MEGN540. MECHATRONICS. 3.0 Semester Hrs.
A course focusing on implementation aspects of mechatronic and control systems. Significant lab component involving embedded C programming on a mechatronics teaching platform, called a haptic paddle, a single degree-of-freedom force-feedback joystick.
Course Learning Outcomes

- 1. Become proficient in mechanical system modeling, system identification and simulations.
- 2. Develop an understanding of how control theory is applied and implemented in practice.
- 3. Learn fundamentals of and how to use semiconductor devices in mechatronic systems
- 4. Learn the basics of sensor and actuator theory, design, and application
- 5. Gain experience in embedded C programming for mechatronic systems
- 6. Gain experience in research article reading and technical presentations

MEGN544. ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL. 3.0 Semester Hrs.
Mathematical representation of robot structures. Mechanical analysis including kinematics, dynamics, and design of robot manipulators. Representations for trajectories and path planning for robots. Fundamentals of robot control including, linear, nonlinear and force control methods. Introduction to off-line programming techniques and simulation. 3 hours lecture; 3 semester hours. Prerequisite: EENG307 and MEGN441.
Course Learning Outcomes

- No change

MEGN545. ADVANCED ROBOT CONTROL. 3.0 Semester Hrs.
The goal of this course is to give the students an introduction to a fundamental working knowledge of the main techniques of intelligent learning-based control and their applications in robotics and autonomous systems. Specific topics include neural network based control, model predictive control, reinforcement learning based control, fuzzy logic control, and human-in-the-loop control.

MEGN551. ADVANCED FLUID MECHANICS. 3.0 Semester Hrs.
(I) This first year graduate course covers the fundamentals of incompressible fluid mechanics with a focus on differential analysis and building a strong foundation in the prerequisite concepts required for subsequent study of computational fluid dynamics and turbulence. The course is roughly divided into four parts covering (i) the governing equations of fluid mechanics, (ii) Stokes flows and ideal-fluid flows, (iii) boundary layer flows, and (iv) hydrodynamic stability and transition to turbulence. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Understand the conservation of mass, momentum, and energy in fluid mechanics from both a differential and control volume perspective.
- 2. Understand the competing roles of inertia, pressure, viscosity, body forces, and boundary conditions in diverse fluid flows.
- 3. Understand dimensional and order-of-magnitude analyses, and their applications to Stokes flows, ideal fluid flows, and boundary layer flows.
- 4. Understand the central importance of hydrodynamic stability to fluid mechanics.

MEGN552. VISCOUS FLOW AND BOUNDARY LAYERS. 3.0 Semester Hrs.
(I) This course establishes the theoretical underpinnings of fluid mechanics, including fluid kinematics, stress-strain relationships, and derivation of the fluid-mechanical conservation equations. These include the mass-continuity and Navier-Stokes equations as well as the multi-component energy and species-conservation equations. Fluid-mechanical boundary-layer theory is developed and applied to situations arising in chemically reacting flow applications including combustion, chemical processing, and thin-film materials processing. Prerequisite: MEGN451, or CBEN430. 3 hours lecture; 3 semester hours.

MEGN553. COMPUTATIONAL FLUID DYNAMICS. 3.0 Semester Hrs.
Introduction to Computational Fluid Dynamics (CFD) for graduate students with no prior knowledge of this topic. Basic techniques for the numerical analysis of fluid flows. Acquisition of hands-on experience in the development of numerical algorithms and codes for the numerical modeling and simulation of flows and transport phenomena of practical and fundamental interest. Capabilities and limitations of CFD. Prerequisite: MEGN451.

MEGN560. DESIGN AND SIMULATION OF THERMAL SYSTEMS. 3.0 Semester Hrs.

In this course the principles of design, modeling, analysis, and optimization of processes, devices, and systems are introduced and applied to conventional and advanced energy conversion systems. It is intended to integrate conservation principles of thermodynamics (MEGN261) with the mechanism relations of fluid mechanics (MEGN351) and heat transfer (MEGN471). The course begins with general system design approaches and requirements and proceeds with mathematical modeling, simulation, analysis, and optimization methods. The design and simulation of energy systems is inherently computational and involves modeling of thermal equipment, system simulation using performance characteristics, thermodynamic properties, mechanistic relations, and optimization (typically with economic-based objective functions). Fundamental principles for steady-state and dynamic modeling are covered. Methods for system simulation which involves predicting performance with a given design (fixed geometry) are studied. Analysis methods that include Pinch Technology, Exergy Analysis, and Thermo-economics are examined and are considered complementary to achieving optimal designs. Optimization encompasses objective function formulation, systems analytical methods, and programming techniques. System optimization of the design and operating parameters of a configuration using various objective functions are explored through case studies and problem sets. Economics and optimization for analyses and design of advanced energy systems, such as Rankine and Brayton cycle power plants, combined.

MEGN561. ADVANCED ENGINEERING THERMODYNAMICS. 3.0 Semester Hrs.

First year graduate course in engineering thermodynamics that emphasizes a greater depth of study of undergraduate subject matter and an advancement to more complex analyses and topics. The course begins with fundamental concepts, 1st and 2nd Law analyses of processes, devices, and systems and advances to equations of state, property relations, ideal and non-ideal gas mixtures, chemically reacting systems, and phase equilibrium. Historical and modern contexts on the development and advancements of thermodynamic concepts are given. Fundamental concepts are explored through the analysis of advanced thermodynamic phenomena and use of computational tools to solve more realistic problems. 3 hours lecture; 3 semester hours. Prerequisite: MEGN261, MEGN351, and MEGN471.

Course Learning Outcomes

- 1. Understand the fundamental theory of the 1st and 2nd Laws of Thermodynamics
- 2. Recognize critical assumptions, property relations, and approaches for different physical situations
- 3. Understand how thermodynamic problems are solved and solve them using available computational tools and techniques
- 4. Use engineering thermodynamics in their research work or applications

MEGN566. COMBUSTION. 3.0 Semester Hrs.

(I) An introduction to combustion. Course subjects include: the development of the Chapman-Jouget solutions for deflagration and detonation, a brief review of the fundamentals of kinetics and thermochemistry, development of solutions for diffusion flames and premixed flames, discussion of flame structure, pollutant formation, and combustion in practical systems. Prerequisite: MEGN451 or CBEN430. 3 hours lecture; 3 semester hours.

MEGN567. PRINCIPLES OF BUILDING SCIENCE. 3.0 Semester Hrs.

First or second year graduate course that covers the fundamentals of building energy systems, moist air processes, heating, ventilation, and air conditioning (HVAC) systems and the use of numerical models for heat and mass transfer to analyze advanced building technologies such as phase change materials, green roofs or cross laminated timber. 3 hours lecture; 3 semester hours. Prerequisite: MEGN261, MEGN351, MEGN471.

Course Learning Outcomes

- 1. Understand and apply fundamental principles to HVAC design
- 2. Describe components in HVAC systems
- 3. Understand how building HVAC loads are calculated and calculate building HVAC loads
- 4. Analyze advance building technologies using building energy simulations tools
- 5. Write technical report based on energy modeling results

MEGN569. FUEL CELL SCIENCE AND TECHNOLOGY. 3.0 Semester Hrs.

Equivalent with CBEN569,CHEN569,MLGN569,MTGN569,

(I) Investigate fundamentals of fuel-cell operation and electrochemistry from a chemical-thermodynamics and materials- science perspective. Review types of fuel cells, fuel-processing requirements and approaches, and fuel-cell system integration. Examine current topics in fuel-cell science and technology. Fabricate and test operational fuel cells in the Colorado Fuel Cell Center. 3 credit hours.

MEGN570. ELECTROCHEMICAL SYSTEMS ENGINEERING. 3.0 Semester Hrs.

In this course, students will gain fundamental, quantitative insight into the operation of electrochemical devices for engineering analysis across a range of length scales and applications. The course will use the development of numerical models as a lens through which to view electrochemical devices. However, the course will also deal extensively with "real world" systems and issues, including experimental characterization, system optimization and design, and the cyclical interplay between models and physical systems. The course begins by establishing the equations that govern device performance at the most fundamental level, describing chemical and electrochemical reactions, heat transfer, transport of charged and neutral species, and material properties in operating devices. Subsequently, these equations will be used to discuss and analyze engineering issues facing three basic types of electrochemical devices: fuel cells, batteries, and sensors. At each juncture will evaluate our equations to determine when simpler models may be more suitable. Throughout the semester, concepts will be applied in homework assignments, including an over-arching, semester-long project to build detailed numerical models for an application of each student's choosing. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- 1. Apply conservation of mass, species and energy to model electrochemical processes and predict performance.
- 2. Use numerical simulations to design and optimize electrochemical systems.
- 3. Given multiple alternatives, students will choose an appropriate level of detail for charge transfer and mass transport models.
- 4. Interpret model simulation results to identify limiting physical processes in a given electrochemical device.

MEGN571. ADVANCED HEAT TRANSFER. 3.0 Semester Hrs.
An advanced course in heat transfer that supplements topics covered in MEGN471. Derivation and solution of governing heat transfer equations from conservation laws. Development of analytical and numerical models for conduction, convection, and radiation heat transfer, including transient, multidimensional, and multimode problems. Introduction to turbulence, boiling and condensation, and radiative transfer in participating media.

MEGN579. OPTIMIZATION MODELS IN MANUFACTURING. 3.0 Semester Hrs.
This course addresses the mathematical formulation and solution of optimization models relevant in manufacturing operations. The types of optimization models examined include: (i) network models; (ii) linear programs; (iii) integer programs; and (iv) nonlinear programs. Application areas include scheduling, blending, design, equipment replacement, logistics and transportation, among other topics. Students learn not only how to mathematically formulate the models, but also how to solve them with a state-of-the-art modeling language (AMPL) and appropriate solver (e.g. CPLEX or Minos). Algorithms for each problem class will be briefly discussed.
Course Learning Outcomes

- Understand the concepts of optimization as applied in a manufacturing setting. See Syllaubs

MEGN583. ADDITIVE MANUFACTURING. 3.0 Semester Hrs.
Additive Manufacturing (AM), also known as 3D Printing in the popular press, is an emerging manufacturing technology that will see widespread adoption across a wide range of industries during your career. Subtractive Manufacturing (SM) technologies (CNCs, drill presses, lathes, etc.) have been an industry mainstay for over 100 years. The transition from SM to AM technologies, the blending of SM and AM technologies, and other developments in the manufacturing world has direct impact on how we design and manufacture products. This course will prepare students for the new design and manufacturing environment that AM is unlocking. The graduate section of this course differs from the undergraduate section in that graduate students perform AM-related research. While students complete quizzes and homework, they do not take a midterm or final exam. Prerequisites: MEGN200 and MEGN201 or equivalent project classes. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Succinctly state differences between AM and SM, and cases where AM or SM is the better technology choice
- 2. Describe all major AM technologies and their applications (FFDM, SLS, etc…)
- 3. Use a software tool chain to bring an assembly from engineering concept to prototype production
- 4. Perform an engineering and economic analysis to determine if AM is appropriate for an engineered part, what AM process is appropriate, and where the economic break-over points are between using one AM technology versus another or SM.
- 5. Use a 3D scanner to obtain 3D data
- 6. Select post processing technique(s) to achieve desired part characteristics for AM part
- 7. Understand the various materials available for use in AM systems
- 8. Understand quality assurance requirements and the process for implementing AM parts into production articles
- 9. Understand qualification and certification methodology
- 10. Conducting research in Additive Manufacturing and Technology

MEGN584. MODELING MATERIALS PROCESSING. 3.0 Semester Hrs.
This course aims to enable students to examine a given materials processing operation or manufacturing problem, identify the important phenomena, develop simple quantitative models of those phenomena, and apply them to obtain reasonable solutions to practical design issues and problems. Phenomena involving fluid flow, heat transfer, solidification, diffusion, and thermal-mechanical behavior are related to terms in governing equations based on heat, mass, and momentum balances. These equations are simplified by formal estimation and scaling to create mechanistic process models, often selected from classic analytical solutions. Example applications to manufacturing processes for metals and polymers include controlled cooling, extrusion, casting, and welding. Prerequisite: Undergraduate degree in Mechanical Engineering or equivalent (that includes relevant courses of calculus, differential equations, materials and/or manufacturing, heat transer, fluid mechanics, and solid mechanics) or instructor consent.
Course Learning Outcomes

- 1) Understand basic processes used in manufacturing materials. Examples presented in class include -controlled cooling -polymer processing (extrusion, molding) -metal casting (sand, metal-mold, continuous, crystal growth, welding) -other processes of interest to the class (based on first-day survey)
- 2) Identify basic phenomena important to specific materials processes -fluid flow (laminar and turbulent; Newtonian and non-Newtonian) -energy transport (transient heat conduction, advection / conduction, forced and natural convection, radiation, viscous dissipation) -solidification (including heat transfer, microstructure development and segregation) -diffusion (solid state and liquid state) -mechanical behavior (thermal stress)
- 3) Write the governing equations to quantify understanding of these phenomena in the context of a particular materials process. -balance equations (energy, mass, momentum) in both global and differential forms -how balance equations are modified to include phenomena such as solidification -choose and transform between Lagrangian and Eulerian reference frames as needed.
- 4) Understand the relationship between physical phenomena and corresponding terms in the governing equations
- 5) Apply formal estimation and scaling to the governing equations to derive appropriate dimensionless groups to evaluate the importance of particular phenomena to a given materials process or problem and to obtain initial estimates of important parameters.
- 6) Decide what phenomena/terms are important, and develop simple, but reasonable, mechanistic mathematical models of materials processes.
- 7) Make approximations to these equations to obtain solutions quickly to a given problem in materials processing: - derive particular analytical solutions by applying appropriate boundary conditions - select appropriate classic analytical solutions - solve to obtain quick quantitative solutions and - evaluate the significance of the solutions and make appropriate recommendations

MEGN585. NETWORK MODELS. 3.0 Semester Hrs.
We examine network flow models that arise in manufacturing, energy, mining, transportation and logistics: minimum cost flow models in transportation, shortest path problems in assigning inspection effort on a manufacturing line, and maximum flow models to allocate machine-hours to jobs. We also discuss an algorithm or two applicable to each problem class. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- 1. Understand how to differentiate spanning tree, shortest path, maximum flow and minimum cost flow models.
- 2. Understand how to graphically depict and mathematically model spanning tree, shortest path, maximum flow and minimum cost flow models.
- 3. Understand algorithms that solve model spanning tree, shortest path, maximum flow and minimum cost flow models.
- 4. Understand the difference between network and non-network optimization models

MEGN586. LINEAR OPTIMIZATION. 3.0 Semester Hrs.
We address the formulation of linear programming models, linear programs in two dimensions, standard form, the Simplex method, duality theory, complementary slackness conditions, sensitivity analysis, and multi-objective programming. Applications of linear programming models include, but are not limited to, the areas of manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year.
Course Learning Outcomes

- Understand how to formulate linear optimization models
- Understand how to solve linear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- Understand the special structure underlying linear optimization models and how this affects their ability to be solved.
- Understand sensitivity and post-optimality analysis.

MEGN587. NONLINEAR OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN487,
This course addresses both unconstrained and constrained nonlinear model formulation and corresponding algorithms (e.g., Gradient Search and Newton's Method, and Lagrange Multiplier Methods and Reduced Gradient Algorithms, respectively). Applications of state-of-the-art hardware and software will emphasize solving real-world engineering problems in areas such as manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with an algorithm such as MINOS) these optimization problems is introduced. Offered every other year. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate nonlinear optimization models.
- 2. Understand how to solve nonlinear optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying nonlinear optimization models and how this affects their ability to be solved.

MEGN588. INTEGER OPTIMIZATION. 3.0 Semester Hrs.
Equivalent with MEGN488,
(I) This course addresses the formulation of integer programming models, the branch-and-bound algorithm, total unimodularity and the ease with which these models are solved, and then suggest methods to increase tractability, including cuts, strong formulations, and decomposition techniques, e.g., Lagrangian relaxation, Benders decomposition. Applications include manufacturing, energy, mining, transportation and logistics, and the military. Computer use for modeling (in a language such as AMPL) and solving (with software such as CPLEX) these optimization problems is introduced. Offered every other year. 3 hours lecture; 3 semester hours. Prerequisite: MATH111.
Course Learning Outcomes

- 1. Understand how to formulate linear-integer optimization models.
- 2. Understand how to solve linear-integer optimization models, both by hand and with the computer through an algebraic modeling language and a state-of-the-art solver.
- 3. Understand the special structure underlying linear-integer optimization models and how this affects their ability to be solved.
- 4. Understand decomposition techniques to aid in solution.

MEGN592. RISK AND RELIABILITY ENGINEERING ANALYSIS AND DESIGN. 3.0 Semester Hrs.
The importance of understanding, assessing, communicating, and making decisions based in part upon risk, reliability, robustness, and uncertainty is rapidly increasing in a variety of industries (e.g.: petroleum, electric power production, etc.) and has been a focus of some industries for many decades (e.g.: nuclear power, aerospace, automotive, etc). This graduate class will provide the student with a technical understanding of and ability to use common risk assessment tools such as Reliability Block Diagrams (RBD), Failure Modes and Effects Analysis (FMEA), and Probabilistic Risk Assessment (PRA); and new tools being developed in universities including Function Failure Design Methods (FFDM), Function Failure Identification and Propagation (FFIP), and Uncoupled Failure Flow State Reasoning (UFFSR) among others. Students will also be provided with a high-level overview of what risk really means and how to contextualize risk information. Methods of communicating and making decisions based in part upon risk information will be discussed.
Course Learning Outcomes

- Understand and be able to use probability statistics
- Understand and be able to use Bayesian statistical methods
- Demonstrate ability to use PRA software
- Demonstrate ability to model a complex engineered system using several (RBD, FMEA, PRA, FFDM, etc) risk and reliability methods

MEGN597. CASE STUDY - MATERIALS SCIENCE. 0.5-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member.

MEGN598. SPECIAL TOPICS IN MECHANICAL ENGINEERING. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN651. ADVANCED COMPUTATIONAL FLUID DYNAMICS. 3.0 Semester Hrs.
This course covers the fundamentals of computational fluid dynamics (CFD) for unsteady incompressible fluids flows, including examples of heat and mass transport. The course focuses on finite-difference methods, finite volume-methods, efficient projection methods for simulating unsteady flows, and recent advances in immersed boundary methods for complicated geometries. The course is entirely based on weekly homeworks, through which students will learn to how build and benchmark their own CFD codes. By the end of the course, students should have the required fundamentals to either build their own research codes, or use commercial and open source CFD codes intelligently. Prerequisites: MEGN502 and MEGN551 are recommended.
Course Learning Outcomes

- 1)
- 2)
- 3)
- 4)

MEGN671. RADIATION HEAT TRANSFER. 3.0 Semester Hrs.
Accurate radiative transfer models are essential in many fields, including: combustion, propulsion, astronomy, solar technology, and climate science, to name only a few. The complex nature of radiative transfer can be intimidating, and calculations can be computationally expensive. In the first half of this course, we will study the role of material and surface properties on radiative transfer and develop and solve models for radiation exchange between surfaces (applicable to solar technology and high temperature systems). In the second half of the course, we will tackle radiation propagation through absorbing, scattering, and emitting media (gases, aerosols, semitransparent materials). We will model these systems using the Radiative Transfer Equation (RTE) and explore a few approaches to solving the RTE for select environments. Prerequisite: MEGN471.
Course Learning Outcomes

- 1. Describe the spectral dependence (particularly blackbody spectral distributions) and directional dependence of radiation heat transfer.
- 2. Apply electromagnetic wave theory to model surface properties and radiation propagation through absorbing media.
- 3. Model and quantitatively calculate net radiation transfer between surfaces, including diffuse, specular, and non-gray surfaces.
- 4. Select methods for measuring radiative properties (e.g. spectral emissivity, absorption cross section), and describe the working principles of the instruments.
- 5. Calculate band absorption and emission for gases using spectral databases (e.g. HITRAN via SpectraPlot).
- 6. Use optical properties to calculate absorption and scattering by particulates.
- 7. Write the appropriate form of the Radiative Transfer Equation (RTE) required to model ra- diation propagating through absorbing, scattering, and emitting media (gases, liquids, and solids).
- 8. Apply select techniques to solve the RTE (including absorption, scattering, and emission) in planar and higher dimensional systems.
- 9. Successfully model a radiation heat transfer problem of your choosing, perform needed computations using appropriate computer software, and summarize your findings in written and oral reports.

MEGN686. ADVANCED LINEAR OPTIMIZATION. 3.0 Semester Hrs.
(II) As an advanced course in optimization, we expand upon topics in linear programming: advanced formulation, the dual simplex method, the interior point method, algorithmic tuning for linear programs (including numerical stability considerations), column generation, and Dantzig-Wolfe decomposition. Time permitting, dynamic programming is introduced. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Offered every other year. Prerequisite: MEGN586. 3 hours lecture; 3 semester hours.
Course Learning Outcomes

- Understand how to formulate complicated linear optimization models.
- Dual Simplex Method and Interior Point Method
- Algorithmic Tuning
- Column Generation and Dantzig-Wolfe Decomposition

MEGN688. ADVANCED INTEGER OPTIMIZATION. 3.0 Semester Hrs.
(II) As an advanced course in optimization, we expand upon topics in integer programming: advanced formulation, strong integer programming formulations (e.g., symmetry elimination, variable elimination, persistence), in-depth mixed integer programming cuts, rounding heuristics, constraint programming, and decompositions. Applications of state-of-the-art hardware and software emphasize solving real-world problems in areas such as manufacturing, mining, energy, transportation and logistics, and the military. Computers are used for model formulation and solution. Prerequisite: MEGN588. 3 hours lecture; 3 semester hours. Years to be Offered: Every Other Year.
Course Learning Outcomes

- 1. Know how to formulate advanced integer optimization models 2. Be familiar with advanced algorithms to solve these models 3. Be able to use software, including scripting, to model and solve these models 4. Understand the theory behind and mathematical tenants of advanced integer optimization models

MEGN698. SPECIAL TOPICS. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

MEGN699. INDEPENDENT STUDY. 0.5-6 Semester Hr.
(I, II, S) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: ?Independent Study? form must be completed and submitted to the Registrar. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/ experience and maximums vary by department. Contact the Department for credit limits toward the degree.

MEGN707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.
(I, II, S) Research credit hours required for completion of a Masters-level thesis or Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit.