Department of Mechanical Engineering Courses

Note on Course Numbers

Each Carnegie Mellon course number begins with a two-digit prefix which designates the department offering the course (76-xxx courses are offered by the Department of English, etc.). Although each department maintains its own course numbering practices, typically the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. xx-6xx courses may be either undergraduate senior-level or graduate-level, depending on the department. xx-7xx courses and higher are graduate-level. Please consult the Schedule of Classes (https://enr-apps.as.cmu.edu/open/SOC/SOCServlet) each semester for course offerings and for any necessary pre-requisites or co-requisites.

24-101 Fundamentals of Mechanical Engineering
Fall and Spring: 12 units
The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. The course is intended primarily for CIT first year students.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-200 Machine Shop Practice
Fall and Spring: 1 unit
This 6 week mini course familiarizes students with the operation and safety of machine tools. This gives students knowledge of what goes into engineering designs in building a prototype and also enables them to operate shop machinery as a part of future courses. Prerequisite: Undergraduate Mechanical Engineering standing Machine Shop Practices should be completed prior to Design I 24-370. However, if necessary, it may be scheduled concurrently with Design I in the first mini of the semester.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-202 Introduction to Computer Aided Design
Fall and Spring: 1 unit
Introduction to computer aided mechanical design using SolidWorks 3D CAD software. Includes the creation and analysis of components and assemblies, generation of drawings, and exporting for manufacture. Two hours of guided computer lab work each week. Prerequisite: Undergraduate Mechanical Engineering standing

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-210 Special Topics: Additive Manufacturing for Engineers
Spring: 3 units
Introduction to additive manufacturing (AM) fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended design project. Completion of 24-202 Intro to CAD, is required.

24-221 Thermodynamics I
Fall: 10 units
Temperature and thermometry; equations of state for fluids and solids; work, heat, and the first law; internal energy, enthalpy, and specific heats; energy equations for flow; change of phase; the second law, reversibility, absolute temperature, and entropy; combined first and second laws; availability; power and refrigeration cycles. Applications to a wide range of processes and devices. 3 hrs. lec., 1 hour recitation
Prerequisites: (33-121 or 33-151 or 33-141 or 33-106) and 21-122 Min. grade C and 24-101

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-231 Fluid Mechanics
Spring: 10 units
Hydrostatics. Control volume concepts of mass, momentum, and energy conservation. Euler's and Bernoulli's equations. Viscous flow equations. Head loss in ducts and piping systems. Dimensional analysis and similitude as an engineering tool. Measurement techniques. 3 hrs. lec., 1 hr. rec.
Prerequisites: (33-151 or 33-106 or 33-141) and 21-122 Min. grade C

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-261 Statics
Fall: 10 units
This course is the first in a two-semester sequence on the solid mechanics of engineering structures and machines. The course begins with a review of the statics of rigid bodies, which includes the identification of statically indeterminate problems. Two- and three-dimensional statics problems are treated. Thereafter, the course studies stresses and deflections in deformable components. In turn, the topics covered are: simple tension, compression, and shear; thin-walled pressure vessels; torsion; and bending of beams. For each topic, statically indeterminate problems are analyzed and elementary considerations of strength are introduced. 3 hrs. lec., 1 hr. rec./lab.
Prerequisites: 21-122 Min. grade C and (33-106 or 33-141 or 33-151 or 33-121)

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-262 Stress Analysis
Spring: 12 units
This course is the second in a two-semester sequence on the solid mechanics of engineering structures and machines. The basic topics of uniaxial tension/compression, torsion, and flexural deformation from 24-261 are reviewed. Combined loadings and stresses are then treated, which lead to a consideration of failure criteria. Two-dimensional elasticity and the finite element method are introduced. Stress concentrations are quantified analytically, numerically, and with the use of engineering handbooks. Cyclic failure criteria are introduced, and both static and cyclic failure criteria are applied to results from numerical analysis. 3 hrs. lec., 1 hr. rec./lab.
Prerequisites: (33-151 or 33-141 or 33-106) and 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-292 Renewable Energy Engineering
Intermittent: 9 units
Introduction to engineering principles of various renewable energy systems, including the following topics: background on climate change and carbon sequestration, engineering analysis of renewable energy systems such as solar photovoltaic, (solar thermal), wind power, hydropower, wave energy, bio mass energy, geothermal energy, and hydrogen based fuel cells. In addition, transitional energy systems such as nuclear power and advanced combined cycles will be introduced. Both engineering performance and present state of development will be discussed. Students will review and present their progress on various subjects, which will be selected based on personal interest.
Prerequisites: 33-141 or 33-106

Course Website: http://www.cmu.edu/me/

24-302 Mechanical Engineering Seminar I
Fall and Spring: 2 units
The purpose of this course is to help students develop good presentation skills and to provide a forum for presentations and discussions of professional ethics. Students will make at least two presentations, one of which is related to professional ethics. Student grades will be based on their presentation skills and their participation in class discussions. 1 hr. rec.
Prerequisites: Junior standing or permission of instructor

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-311 Numerical Methods
Spring: 12 units
Use of numerical methods for solving engineering problems with the aid of a digital computer. The course will contain numerical methods such as roots of equations, linear algebraic equations, optimization, curve fitting, integration, and differential equation solving. MATLAB will be used as the programming language. Programming cluster laboratory times will be available twice a week. Problems will be drawn from all fields of interest to mechanical engineers. 3 hrs. lecture plus lab
Prerequisite: 21-260

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-321 Thermal-Fluids Experimentation
Spring: 12 units
24-321 Thermal-Fluids Experimentation Spring: 12 units This is a capstone course for the thermal-fluids core-course sequence. This course covers techniques of measurement, uncertainty analysis, and realization of systems, which demonstrate fundamental principles in thermodynamics, fluid mechanics, and heat transfer. The principles of designing thermal experiments are also integrated into this course.
Prerequisites: 24-231 and 24-221 and 24-322

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-322 Heat Transfer
Fall: 10 units
Introduction to basic concepts of engineering heat transfer. Steady and transient heat conduction in solids, including the effect of heat generation. Finned surfaces. Correlation formulas for forced and free convection, condensation, and boiling. Design and analysis of heat exchangers. Radiation heat transfer. Problems in combined convection and radiation. Measurement techniques. 3 hrs. lec., 1 hr. recitation.
Prerequisites: 24-221 and 24-231 and 21-260

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-334 Introduction to Biomechanics
Fall: 9 units
This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.
Prerequisite: 24-231

Course Website: http://www.cmu.edu/me/

24-341 Manufacturing Sciences
Spring: 9 units
This course has two broad concerns: an introductory review of manufacturing systems organization and a review of common manufacturing processes from the point of view of design for manufacturability. The features of mass and batch production are quantitatively considered. The basic principles of group technology and production planning are outlined. The use of computers in manufacturing is described, together with a review of the current capabilities of industrial robots. Students will be involved in weekly seminars, which will describe the basic features of common manufacturing processes, including metal machining, metal forming, polymer processing, casting techniques, joining techniques, ceramic processing, and powder processing. Case studies from industry and films may be used. 3 hrs. rec.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-351 Dynamics
Fall: 10 units
This first course on the modeling and analysis of dynamic systems concentrates on the motion of particles, systems of particles, and rigid bodies under the action of forces and moments. Topics include the kinematics of motion in rectangular, polar, and intrinsic coordinates; relative motion analysis with multiple reference frames; and planar kinetics through the second law, work-energy method, and impulse-momentum method. Time and frequency domain solutions to first and second order equations of motion are discussed. 3 hrs. lec. 1 hr rec.
Prerequisite: 24-261

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-352 Dynamic Systems and Controls
Spring: 12 units
This second course on the modeling and analysis of dynamic systems emphasizes the common features, which are exhibited by physical systems that include mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical elements. State equations and the concepts of equilibrium, linearization, and stability are discussed. Time and frequency domain solutions are developed. 4 hr. lec.
Prerequisites: (33-107 and 24-261 and 21-260) or (21-260 and 33-142 and 24-261) or (33-152 and 24-261 and 21-260) or (24-261 and 33-132 and 21-260)

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-354 Special Topics: Gadgetry: Sensors, Actuators, and Processors
Fall: 9 units
This course will introduce the components used in mechatronic design. Topics include microcontrollers, circuit design and analysis, and sensors and actuators commonly used in mechatronic systems. The course will contain a substantial hands-on component in which students will program microcontrollers to read sensors and drive actuators. This course is a pre-requisite for 24-671 Electromechanical Systems Design, which can substitute for 24-441 to satisfy the capstone design requirement.
Prerequisites: (15-110 or 15-112) and (33-152 or 33-107 or 33-142)

Course Website: http://www.cmu.edu/me/

24-358 Special Topics in Culinary Mechanics
Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence food and the culinary arts. The aim of the course is to apply important aspects of mechanics to ideas in cooking. Specific topics include: (1) how do stress and strain affect food and its perceived taste; (2) what is the role of cell mechanics in the resulting micro structure of both consumed plant and animal tissues; (3) how can mechanics be used to alter nutrition; (4) what are the roles of common and uncommon mechanical tools such as a knife or mortar and pestle in food preparation. Emphasis will be placed on the biomechanics of edible matter across multiple length scales, including at the tissue, cellular, and molecular levels; additionally, impact on global health and engineering implications will be elucidated. During this course, we will introduce you to these concepts,train you to use them in real world applications, and allow you to pursue a creative group-defined project, which will be shared in both written and oral formats. We will integrate a hands-on kitchen experience in at least 3 specific laboratory classes so that students will get a true feel and understanding for culinary mechanics. We also will be visiting the restaurant of at least one first-rate Pittsburgh chef to gain real world insight into mechanics and cooking.

Course Website: http://www.cmu.edu/me/

24-370 Engineering Design I: Methods and Skills
Fall: 12 units
In this course, students will learn methods and skills for the engineering design process, consisting of four stages: concept design, detail design, analysis, and manufacturing. The course covers the engineering design process in a holistic fashion by discussing theories and practices of the four stages and inter-relating them. Hands-on assignments, including computational and physical projects, are given to enhance the learning outcome. After taking this course, students will be able to: express ideas in sketches; interpret and create engineering drawings; select and apply machine elements; model detailed shapes with CAD tools; analyze product performance with CAE tools; choose materials and manufacturing schemes, and create and test prototypes. Recommended: 24-200 (machine shop practice).
Prerequisites: 24-202 Min. grade C and 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-391 Mechanical Engineering Project
Fall and Spring
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-392 Mechanical Engineering Project
All Semesters
Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-421 Internal Combustion Engines
Fall: 12 units
This course discusses working principles of internal combustion engines found in many practical applications. Focus is given to understanding the design of air handing system, in-cylinder fuel/air mixing, geometric design of the combustion chamber, engine performance and calibration, and mechanism of pollutant formation and reduction. Introductory discussion of advanced automotive engine concepts, alternative fuels, gas turbine engines, rocket engines, and hybrid electric vehicles is also provided. The course relies on a number of lab experiments, analysis of actual experimental data, and a combination of analytical and numerical homework assignments. 3 hrs. lecture 2 hrs. lab
Prerequisites: 24-221 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24421/

24-424 Energy and the Environment
Fall: 9 units
Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor. 3 hrs lecture

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-425 Combustion and Air Pollution Control
Intermittent: 9 units
Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples. 3 hours lecture Cross listed as 24-740 and 19440/19-740

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-441 Engineering Design II: Conceptualization and Realization
Fall and Spring: 12 units
This course guides students through the design process in the applied design of a practical mechanical system. Lectures describe the typical design process and its associated activities, emphasizing methods for innovation and tools for design analysis. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is typically completed in teams and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation. Frequently, a working model will also be required. Oral progress reports and a final written and oral report are required. 3 hrs. rec., 3 hrs lab Senior standing and Machine Shop Practice 24-200 required.
Prerequisites: 24-370 and 24-262

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-451 Feedback Control Systems
Fall: 12 units
Fundamentals of feedback control with emphasis on classical techniques and an introduction to discrete-time (computer controlled) systems. Topics include the following: frequency domain modeling and state space modeling of dynamical systems; feedback control system concepts and components; control system performance specifications such as stability, transient response, and steady state error; analytical and graphical methods for analysis and design - root locus, Bode plot, Nyquist criterion; design and implementation of proportional, proportional-derivative, proportional-integral-derivative, lead, lag, and lead-lag controllers. Extensive use of computer aided analysis and design software. 4 hrs lec.
Prerequisites: (15-112 or 15-110) and 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-452 Mechanical Systems Experimentation
Fall: 9 units
Experimentation in dynamic systems and controls. The course will cover translational and rotational systems. Topics will include mechanical elements, natural frequencies, mode shapes, free and forced response, frequency response and Bode plots, time constants, transient response specifications, feedback controls such as PID control, and stability for single-degree-of-freedom and multi-degree-freedom systems. The course will introduce and use state-of-the-art experimentation hardware and software. 24-352 Dynamic Systems and Controls- prerequisite- MSE is a fall only senior course.
Prerequisite: 24-352

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-491 Department Research Honors
Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-492 Department Research Honors
Fall and Spring
This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: http://www.cmu.edu/me/undergraduate/index.html

24-612 Cardiovascular Mechanics
Spring: 12 units
The primary objective of the course is to learn to model blood flow and mechanical forces in the cardiovascular system. After a brief review of cardiovascular physiology and fluid mechanics, the students will progress from modeling blood flow in a.) small-scale steady flow applications to b.) small-scale pulsatile applications to c.) large-scale or complex pulsatile flow applications. The students will also learn how to calculate mechanical forces on cardiovascular tissue (blood vessels, the heart) and cardiovascular cells (endothelial cells, platelets, red and white blood cells), and the effects of those forces. Lastly, the students will learn various methods for modeling cardiac function. When applicable, students will apply these concepts to the design and function of selected medical devices (heart valves, ventricular assist devices, artificial lungs).
Prerequisite: 24-231

24-614 Microelectromechanical Systems
Intermittent: 12 units
This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments.
Prerequisites: 18-321 or 24-351

Course Website: http://www.cmu.edu/me/graduate/index.html

24-615 Microfluidics
Intermittent: 12 units
This course offers an introduction to the emerging field of microfluidics with an emphasis on chemical and life sciences applications. During this course students will examine the fluid dynamical phenomena underlying key components of "lab on a chip" devices. Students will have the opportunity to learn practical aspects of microfluidic device operation through hands-on laboratory experience, computer simulations of microscale flows, and reviews of recent literature in the field. Throughout the course, students will consider ways of optimizing device performance based on knowledge of the fundamental fluid mechanics. Students will explore selected topics in more detail through a semester project. Major course topics include pressure-driven and electrokinetically-driven flows in microchannels, surface effects, micro-fabrication methods, micro/nanoparticles for biotechnology, biochemical reactions and assays, mixing and separation, two-phase flows, and integration and design of microfluidic chips. Undergraduate Fluid Mechanics prerequisite or instructor permission 4 hrs. lecture
Prerequisite: 24-231

Course Website: http://www.cmu.edu/me/graduate

24-618 Special Topics: Computational Analysis of Transport Phenomena
Spring: 12 units
In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report. Detailed syllabus of the course is provided on the URL given below.
Prerequisites: 24-221 and 24-322 and 24-231

Course Website: http://www.andrew.cmu.edu/user/satbirs/24618/

24-623 Molecular Simulation of Materials
Spring: 12 units
The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.
Prerequisites: 24-311 and 24-221

Course Website: http://www.cmu.edu/me/graduate/index.html

24-626 Air Quality Engineering
Intermittent: 12 units
The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines. 12 units
Prerequisites: 36-220 and 09-105 and 24-231

Course Website: http://www.cmu.edu/me/

24-628 Energy Transport and Conversion at the Nanoscale
Spring: 12 units
Energy transport and conversion processes occur at the nanoscale due to interactions between molecules, electrons, phonons, and photons. Understanding these processes is critical to the design of heat transfer equipment, thermoelectric materials, electronics, light emitting diodes, and photovoltaics. The objective of this course is to describe the science that underlies these processes and to introduce the contemporary experimental and theoretical tools used to understand them. The course includes a laboratory that gives the students experience with modern transport measurement instrumentation and data analysis. Integrated literature reviews and a final project require students to apply learned fundamentals to understand state-of-the-art research and technology. 4 hrs. lecture
Prerequisites- 24-322 & 24-221 or equivalents
Prerequisites: 24-221 and 24-322

Course Website: http://www.cmu.edu/me/graduate/index.html

24-629 Direct Solar and Thermal Energy Conversion
Intermittent: 12 units
This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology 12 units

Course Website: http://www.cmu.edu/me/

24-642 Fuel Cell Systems
Fall: 12 units
Fuel cells are devices that convert chemical potential energy directly into electrical energy. Existing fuel cell applications range from the small scale, such as portable cell phone chargers, to the large scale, such as MW-scale power plants. Depending on the application, fuel cell systems offer unique advantages and disadvantages compared with competing technologies. For vehicle applications, they offer efficiency and environmental advantages compared with traditional combustion engines. In the first half of the course, the focus is on understanding the thermodynamics and electrochemistry of the various types of fuel cells, such as calculating the open circuit voltage and the sources of voltage loss due to irreversible processes for the main fuel cells types: PEM/SOFC/MCFC. The design and operation of several real fuel cells are then compared against this theoretical background. The second half of the course focuses on the balance-of-plant requirements of fuel cell systems, such as heat exchangers, pumps, fuel processors, compressors, as well as focusing on capital cost estimating. Applying the material learned from the first and second halves of the class into a final project, students will complete an energy & economic analysis of a fuel cell system of their choice. Prerequisite- Undergraduate Thermodynamics course 12 units
Prerequisites: 06-221 or 24-221 or 27-215

Course Website: http://www.cmu.edu/me/graduate/index.html

24-650 Applied Finite Element Analysis
Intermittent: 12 units
This is an introductory course on the finite element method with emphasis on application of the method to a wide variety of problems. The theory of finite element analysis is presented and students learn various applications of the method through assignments utilizing standard finite element software packages commonly used in industry. Various types of analyses are considered, which may include, for example, static, pseudo-static, dynamic, modal, buckling, contact, heat transfer, thermal stress and thermal shock. Students also learn to use a variety of element types in the models created, such as truss, beam, spring, solid, plate, and shell elements.
Prerequisites: 24-322 and 24-262

24-651 Material Selection for Mechanical Engineers
Spring: 12 units
This course provides a methodology for selecting materials for a given application. It aims to provide an overview of the different classes of materials (metal, ceramic, glass, polymer, elastomer or hybrid) and their properties including modulus, strength, ductility, toughness, thermal conductivity, and resistance to corrosion in various environments. Students will also learn how materials are processed and shaped (e.g., injection molding, casting, forging, extrusion, etc.), and will explore the origins of the properties, which vary by orders of magnitude. Topics include: Materials selection by stiffness, strength, fracture toughness and fatigue. Shape factors and materials processing. Binary phase and time temperature transformation diagrams, microstructure. Polymer types and structures. Alloying and strengthening of metals, types of steels. Corrosion, oxidation, tribology and thermal properties.
Prerequisites: 09-105 and 24-262

Course Website: http://www.cmu.edu/me/

24-655 Cellular Biomechanics
Intermittent: 9 units
This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec.
Prerequisite: Instructor permission.

Course Website: http://www.cmu.edu/me/graduate/index.html

24-657 Molecular Biomechanics
Intermittent: 9 units
This class is designed to present concepts of molecular biology, cellular biology and biophysics at the molecular level together with applications. Emphasis will be placed both on the biology of the system and on the fundamental physics, chemistry and mechanics which describe the molecular level phenomena within context. In addition to studying the structure, mechanics and energetics of biological systems at the nano-scale, we will also study and conceptually design biomimetic molecules and structures. Fundamentals of DNA, globular and structured proteins, lips and assemblies thereof will be covered.
Prerequisites: 24-221 or 06-221

Course Website: http://www.cmu.edu/me

24-658 Computational Bio-Modeling and Visualization
Spring: 12 units
Biomedical modeling and visualization play an important role in mathematical modeling and computer simulation of real/artificial life for improved medical diagnosis and treatment. This course integrates mechanical engineering, biomedical engineering, computer science, and mathematics together. Topics to be studied include medical imaging, image processing, geometric modeling, visualization,computational mechanics, and biomedical applications. The techniques introduced are applied to examples of multi-scale biomodeling and simulations at the molecular, cellular, tissue, and organ level scales. 4 hrs. lec./lab

Course Website: http://www.cmu.edu/me/graduate/index.html

24-671 Special Topics: Electromechanical Systems Design
Fall and Spring: 12 units
This course guides students through the design process as applied to mechatronic systems, which feature electrical, mechanical, and computational components. Lectures describe the typical design process and its associated activities, emphasizing methods for analyzing and prototyping mechatronic systems. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is team-based and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation and a working prototype system at the end of the course. Oral progress reports and a final written and oral report are required.
Prerequisites: (16-311 or 24-354) and 24-370 and 24-352

Course Website: http://www.cmu.edu/me/

24-672 Special Topics in DIY Design and Fabrication
Fall: 12 units
The traditional principles of mass production are being challenged by concepts of highly customized and personalized goods. A growing number of do-it-yourself (DIY) inventors, designers, makers, and entrepreneurs is accelerating this trend. This class offers students hands-on experience in DIY product design and fabrication processes. Over the course of the semester, students work individually or in small groups to design customized and personalized products of their own and build them using various DIY fabrication methods, including 3D laser scanning, 3D printing, laser cutting, molding, vacuum forming, etc. In addition to design and fabrication skills, the course teaches students skills for communicating their ideas effectively through industrial design sketches and presenting their products with aesthetically refined graphics.

Course Website: https://www.andrew.cmu.edu/course/24-672/

24-673 Soft Robots: Mechanics, Design and Modeling
Spring: 12 units
Soft, elastically-deformable machines and electronics will dramatically improve the functionality, versatility, and biological compatibility of future robotic systems. In contrast to conventional robots and machines, these ? soft robots? will be composed of elastomers, gels, fluids, gas, and other non-rigid matter. We will explore emerging paradigms in soft robotics and study their design principles using classical theories in solid mechanics, thermodynamics, and electrostatics. Specific topics include artificial muscles, peristaltic robotics, soft pneumatic robotics, fluid-embedded elastomers, and particle jamming. This course will include a final project in which students may work individually or as a team. For the project, students are expected to design and simulate and/or build all or part (eg. sensors, actuators, grippers, etc.) of a soft robot. Prerequisites: Statics and Stress Analysis or equivalents.
Prerequisite: 24-262

Course Website: http://www.cmu.edu/me/

24-674 Design of Biomechatronic Systems for Humans
Intermittent: 12 units
This course explores methods for the design of electromechanical devices that physically interface with humans to improve biomechanical performance, such as robotic prostheses and exoskeletons. Students will learn about common physical disabilities and methods for generating and evaluating potential interventions. Students will learn about state-of-the-art actuation and sensing systems, and design selected types to meet dynamic performance criteria. We will cover technology for interfacing these devices with humans, and implications for the resulting biomechatronic systems. Students will learn experimental methods for evaluating intervention effectiveness, including inverse dynamics and metabolics analyses. Students will complete a final project that involves introduction of novel elements to a biomechatronic system. Students need a foundation in machine design and numerical tools such as Matlab, and will benefit from knowledge of dynamics and biomechanics. Lecture 4 hrs. 12 units
Prerequisites: 24-311 and 24-351 and 24-370

Course Website: http://www.cmu.edu/me/

24-680 Quantitative Entrepreneurship: Analysis for New Technology Commercialization
Intermittent: 12 units
This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design and enterprise planning decisions in an uncertain, competitive market. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, decision-tree analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with basic calculus, linear algebra, and probability theory.
Prerequisite: 21-259

24-681 Computer-Aided Design
Intermittent: 12 units
his course is the first section of the two-semester sequence on computational engineering. Students will learn how computation and information technologies are rapidly changing the way engineering design is practiced in industry. The course covers the theories and applications of the measurement, representation, modeling, and simulation of three-dimensional geometric data used in the engineering designed process. Students taking this course are assumed to have knowledge of the first course in computer programming. 4 hrs lecture, 2 hrs computer cluster

Course Website: http://www.andrew.cmu.edu/course/24-681/

24-683 Design for Manufacture and the Environment
Fall: 12 units
Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

Course Website: http://www.cmu.edu/me/graduate/index.html

24-688 Introduction to CAD and CAE Tools
Fall: 12 units
This course offers the hands-on training on how to apply modern CAD and CAE software tools to engineering design, analysis and manufacturing. In the first section, students will learn through 7 hands-on projects how to model complex free-form 3D objects using commercial CAD tools. In the second section, students will learn through 7 hands-on projects how to simulate complex multi-physics phenomena using commercial CAE tools. Units: 12 Format: 2 hrs. Lec., 2 hrs. computer lab
Prerequisites: 24-231 and 24-262

Course Website: http://www.cmu.edu/me/