Department of Mechanical Engineering

Chairperson:	Lakkis, Issam
Professors:	Darwish, Marwan; Ghali, Kamel; Ghaddar, Nesreen; Hamade, Ramsey; Moukalled, Fadl; Shihadeh, Alan
Professor Emeritus:	Sakkal, Fateh
Associate Professors:	Asmar, Daniel; Lakkis, Issam; Mustapha, Samir; Oweis, Ghanem; Shammas, Elie; Shehadeh, Mutasem
Assistant Professors:	Abou Jaoude, Dany; Aryanfar, Asghar; Awartani, Omar; Harb, Mohammad
Instructors:	Al Saidi, Abdul-Kader; Babikian, Sevag; Balhas, Zainab; Fayad, Rami; Kassis, Lina; Kfoury, Elie

The Department of Mechanical Engineering offers one undergraduate degree program that leads to a Bachelor of Engineering with a major in Mechanical Engineering (BE in ME) and a minor in Applied Energy.

Bachelor of Engineering (BE)

Major: Mechanical Engineering

The Mechanical Engineering Program extends over a four-year period and is offered exclusively on a daytime, on-campus basis. The program is offered in 11 terms whereby eight terms are 16-week Fall/Spring terms given over four years, and three terms are eight-week summer terms taken during the first three years of the program. In the summer term of the third year (Term IX), students are required to participate in a practical training program with a local, regional or international organization. The entire program is equivalent to five academic years but is completed in four calendar years with three summer terms.

The undergraduate program also provides students with options to pursue minors in the following:

- Applied Energy Minor
- Other minors offered by the Maroun Semaan Faculty of Engineering and Architecture, Faculty of Arts and Sciences and the Suliman S. Olayan School of Business

Program Mission

The Mechanical Engineering faculty has agreed that the undergraduate program mission is as follows:

The undergraduate program in Mechanical Engineering seeks to empower students to pursue successful careers and to create a learning environment in which they can develop their creative and critical thinking skills, grow into lifelong learners in light of ever-increasing challenges of modern technology, and commit to the ethical and professional responsibilities required in their calling at the global level while focusing on the needs of Lebanon and the region.

Program Educational Objectives

The program is based on the following educational objectives that were approved by the Mechanical Engineering faculty members on May 27, 2010:

Our graduates will be able to advance successfully in their careers as reflected in continued employment, job satisfaction, leadership responsibilities and professional recognition.

Our graduates will be able to succeed in graduate studies as reflected in admission to highly ranked programs, timely completion of degree requirements and recognition by competitive fellowships and other awards.

Program Requirements

The undergraduate curriculum for the degree of Bachelor of Engineering (BE), major: Mechanical Engineering is a five-year program. It consists of 173 term credit hours of coursework of which 30 credits are completed in the freshman year while the student is enrolled in the Faculty of Arts and Sciences and 143 credits are completed in four years while the student is enrolled in the Maroun Semaan Faculty of Engineering and Architecture. Students admitted at the sophomore level will be required to complete 143 credits in four years to earn the degree as outlined here:

- **General Engineering:** FEAA 200, CIVE 210, EECE 210, EECE 231, EECE 312, EECE 312L, INDE 301
- **Mathematics:** MATH 201, MATH 202, MATH 212, MATH 218, MATH 251, STAT 230
- **Sciences:** PHYS 211, PHYS 211L, CHEM 202, and one biology elective (BIOL 201 level or above, except BIOL 209)
- **General Education:** Arabic course, ENGL 203 and ENGL 206, two social sciences courses, three humanities courses and a course on ethics approved for the GE program
- **ME Core Courses:** MECH 201, MECH 230, MECH 310, MECH 314, MECH 320, MECH 332, MECH 340, MECH 341, MECH 410L, MECH 412, MECH 414, MECH 420, MECH 421, MECH 430, MECH 432, MECH 436, MECH 510 and MECH 520
- **Technical Electives:** Five courses with at least ***three*** from the selected ME track. One elective can be from outside the major ***and one free elective (such as engineering, math, economics, business or science)***
- **Approved Experience:** MECH 500
- **Final Year Project:** MECH 501 and MECH 502

Curriculum

Term I (Fall)		Credits
MATH 201	Calculus and Analytic Geometry III	3
FEAA 200	Introduction to Engineering and Architecture	3
EECE 231	Introduction to Programming using C++ and MATLAB	3
CIVE 210	Statics	3
PHYS 211	Electricity and Magnetism	3
PHYS 211L	Electricity and Magnetism Laboratory	1
		Total 16

Term II (Spring)		Credits
EECE 210	Electric Circuits	3
MECH 201	Computer Aided Drawing and Design (CADD)	3
MATH 202	Differential Equations	3
MECH 230	Dynamics	3
ENGL 203	Academic English	3
		Total 15

Term III (Summer)		Credits
STAT 230	Introduction to Probability and Random Variables	3
CHEM 202	Introduction to Environmental Chemistry	3
ENGL 206	Technical English	3
		Total 9

Term IV (Fall)		Credits
EECE 312	Electronics	3
EECE 312L	Circuits and Electronics Lab	1
MATH 212	Introductory Partial Differential Equations	3
MECH 310	Thermodynamics I	3
MECH 340	Engineering Materials	3
Humanities Elective		3
		Total 16

Term V (Spring)		Credits
MATH 218	Elementary Linear Algebra with Applications	3
MECH 314	Introduction to Fluid Mechanics	3
MECH 320	Mechanics of Materials	3
MECH 332	Mechanics of Machines	3
MECH 341	Materials Lab	1
MECH 430	Process Instrumentation and Measurements	3
		Total 16

Term VI (Summer)		Credits
MECH 432	Dynamics System Analysis	2
Biology Elective		3
Arabic Elective		3
		Total 8

Term VII (Fall)		Credits
MATH 251	Numerical Computing	3
MECH 410L	Thermal Fluid Laboratory	1
MECH 414	Thermodynamics II	3
MECH 420	Mechanical Design I	3
MECH 421	Manufacturing Processes I	3
		Total 16

Term VII (Fall)		Credits
Social Sciences Elective		3
		Total 16

Term VIII (Spring)		Credits
INDE 301	Engineering Economy	3
MECH 412	Heat Transfer	3
MECH 436	Control Systems	3
MECH 520	Mechanical Design II	3
Social Sciences Elective		3
		Total 15

Term IX (Summer)		Credits
MECH 500	Approved Experience	0
Term X (Fall)		**Credits**
MECH 501	Final Year Project	1
MECH 510	Design of Thermal Systems	3
Approved Ethics Course		3
Technical Elective I		3
Technical Elective II		3
Humanities Elective		3
		Total 16

Term XI (Spring)		Credits
MECH 502	Final Year Project II	4
Technical Elective III		3
Technical Elective IV		3
Technical Elective V		3
Humanities Elective		3
		Total 16

List of Pre-Approved Technical Electives

- **Engineering Electives**: BMEN: 600, 602, 604, 605, 606, 609, 610, 611. CHEN: 531, 611, 614, 615, 619, 672, 673, 675, 798A. CIVE: 421, 451, 460, 552, 555, 602, 603, 610, 648, 655, 658, 659, 670. FEAA: 502. IEM: 412, 513, 533.
- **Science Electives**: BIOL: 201, 202, 210, 223, 244, 246, 250, 260, 268. CHEM: 206, 208, 211, 212, 217, 218, 228, 233, 234. MATH: 210, 219, 223, 224, 225, 227, 233, 241, 261, 271, 303, 304, 305, 306, 314, 341, 350, 351, 358. PHYS: 216, 217, 220, 222, 223, 225, 226, 228, 235, 236, 237, 249, 301, 302, 303, 305, 306, 307.
- **Other Electives**: CMPS: 257, 272, 274, 277, 281, 285, 286, 287, 288, 350, 368, 372, 373. DCSN: 200, 210. ECON: 214, 215, 217, 218, 222, 223, 226, 227, 228, 230, 232, 235, 236, 237, 239, 240, 241, 242, 243. ENMT: 225, 235. GEOL: 202, 205, 211, 226, 227. MNGT: 215, 218, 220, 226, 229, 230. STAT: Any course with a number equal to or greater than 234.

Mechanical Engineering Optional Tracks

The core courses in the Mechanical Engineering Program are offered in the following track areas:

- Thermal and Fluid Engineering
- Mechatronics
- Design, Materials and Manufacturing

The student may opt for any track (Thermal and Fluid Engineering; Mechatronics; or Design, Materials and Manufacturing) by taking at least three technical electives in the selected track. Normally one technical elective is allowed from outside the mechanical engineering major.

The ME focus area in Control and Robotics provides a coherent academic framework between the ECE and ME departments in the areas of control, instrumentation and robotics. This track is open to all undergraduate ME and ECE students.

Track I: Thermal and Fluid Engineering		**Credits**
MECH 310	Thermodynamics I	3
MECH 314/ CHEN 311	Introduction to Fluids Engineering	3
MECH 414	Thermodynamics II	3
MECH 410L	Thermal/Fluid Systems Laboratory	1
MECH 412	Heat Transfer	3
MECH 501	Final Year Project I and	1
MECH 502	Final Year Project II	4
MECH 510	Design of Thermal Systems	3

Technical Elective Courses (at least three technical electives are selected)		**Credits**
MECH 511	Intermediate Fluid Mechanics	3
MECH 512	Internal Combustion Engines	3
MECH 513	Air Conditioning	3
MECH 514	Gas Turbines	3
MECH 515	Steam Turbines	3
MECH 516	Aerodynamics	3
MECH 603	Solar Energy	3
MECH 604	Refrigeration	3
MECH 606	Aerosol Dynamics	3
MECH 607	Micro Flows Fundamentals and Applications	3

Track II: Design, Materials and Manufacturing		**Credits**
CIVE 210	Statics	3
MECH 201	Computer Aided Drawing and Design (CADD)	3
MECH 320	Mechanics of Materials	3
MECH 332	Mechanics of Machines	3
MECH 340	Engineering Materials	3
MECH 341L	Materials Lab	1
MECH 420	Mechanical Design I	3
MECH 421	Manufacturing Processes I	3

Track II: Design, Materials and Manufacturing		Credits
MECH 501	Final Year Project I	1
MECH 502	Final Year Project II	4
MECH 520	Mechanical Design II	3

Technical Elective Courses (at least three technical electives are selected)		Credits
MECH 521	Manufacturing Processes II	3
MECH 522	Mechanical CAD/CAE/CAM	3
MECH 540	Selection of Properties of Materials	3
MECH 550	Computer Applications in Mechanical Engineering	3
MECH 615	Continuum Mechanics	3
MECH 617	Smart Materials and Structures	3
MECH 622	Modeling of Machining Processes and Machines	3
MECH 624	Mechanics of Composite Materials	3
MECH 625	Fatigue of Materials	3
MECH 626	Metals and Their Properties	3
MECH 627	Polymers and Their Properties	3
MECH 628	Design of Mechanisms	3
MECH 630	Finite Element Methods in Mechanical Engineering	
MECH 633	Biomechanics	3
MECH 634	Biomaterials and Medical Devices	3

Track III: Mechatronics		Credits
MECH 230	Dynamics	3
EECE 210	Electric Circuits	3
EECE 312	Electronics (for Mechanical Engineering students)	3
EECE 312L	Circuits and Electronics Lab	1
MECH 430	Instrumentation and Measurements	3
MECH 436	Control Systems	3
MECH 501	Final Year Project I and	1
MECH 502	Final Year Project II	4
MECH 653	Systems Analysis and Design	3
MECH 654	Adaptive Control	3

Technical Elective Courses (at least three technical electives are selected)		Credits
MECH 530	Mechatronics System Design	3
MECH 531	Mechanical Vibrations	3
MECH 628	Design of Mechanisms	3
MECH 631	Micro-Electro Mechanical Systems [MEMS]	3
MECH 634	Biomaterials and Medical Devices	3
MECH 641	Robotics	3
MECH 642	Computer Vision	3
MECH 643	Mechatronics and Intelligent Machines Eng. II	3
MECH 644	Modal Analysis	3
MECH 645	Noise and Vibration Control	3

ME Focus Area in Control and Robotics

Students choosing to enroll in the Control and Robotics Focus (CRF) area should satisfy the following course requirements:

Two core courses and one laboratory in their respective departments (listed in the table below)

Core Courses		Credits
MECH 430	Process Instrumentation and Measurements	3
MECH 432	Dynamic System Analysis	2
MECH 436	Control Systems	3

Three elective courses from either department (ECE/ME) (listed in the tables below) provided they obtain the necessary prerequisites for any given course. At least one course from each of lists A (Control Theory) and B (Robotics) must be chosen, and one elective from either list A, B or C.

Technical Elective Courses (List A: Control)		Credits
MECH 648/ EECE 669	Nonlinear Systems: Analysis, Stability and Control	3
MECH 653/ EECE 660	System Analysis and Design	3
MECH 655/ EECE 662	Optimal Control	3
MECH 656/ EECE 663	System Identification	3
MECH 654	Adaptive Control	3

Technical Elective Courses (List B: Robotics)		Credits
MECH 530/ EECE 530	Mechatronics	3
MECH 641/ EECE 661	Robotics	3
MECH 646/ EECE 697	Wheeled Mobile Robotics	3
MECH 650/ EECE 698	Autonomous Mobile Robotics	3

Technical Elective Courses (List C)		Credits
MECH 555/ EECE 463	Artificial Intelligence for Control Systems	3
MECH 642/ EECE 692	Computer Vision	3
MECH 647/ EECE 699	Hydraulic Servo Systems	3

Minor in Applied Energy

The minor in Applied Energy is open to all MSFEA students who are interested in the energy domain and in renewable energy applications. Students seeking professional careers that will focus on energy, the environment, sustainable applications in buildings and energy systems may find this minor attractive. The minor in applied energy is administered by the Department of Mechanical Engineering.

Students who have completed at least 60 credits at the sophomore level and higher and who have a cumulative average of 70 (GPA:2.2) or more may apply by completing a minor application. The minor will be indicated on the transcript of the student who completes all the requirements described below. A minimum grade of 70 (C+) is required for a course to count toward the fulfillment of the minor.

Applied Energy Minor Program Structure

A student wishing to complete the minor is required to complete a minimum of 18 credits: 6 credits from the list of core courses and 12 credits from the list of elective courses.

The first are two core courses (6 credits) that provide a foundation for the understanding of energy science and technology and its economy.

The second component is a number of elective courses (12 credits), selected by the student in close consultation with her/his academic advisor for the applied energy minor.

Required Courses (6 credits)

- MECH 671 Renewable Energy Potential, Technology and Utilization in Buildings 3 cr., or EECE 675 Renewable Energy Systems 3 cr. or ENST 300 The Science and Technology of Energy 3 cr.
- ECON 333 Energy Economics and Policy 3 cr.

Elective Courses (Minimum of 12 credits)

CHEN 417	**Reactor Engineering and Reactor Design**	**3 cr.**
CHEN 470	**Chemical Process Design**	**3 cr.**
CHEN 471	**Chemical Product Design**	**3 cr.**
CHEN 541	**Biochemical and Bioprocess Engineering**	**3 cr.**
CHEN 570	**Process Synthesis and Optimization**	**3 cr.**
CHEN 612	**Desalination**	**3 cr.**
EECE 670	**Power System Planning**	**3 cr.**
EECE 671	**Environmental Aspects of Energy Systems**	**3 cr.**
EECE 672	**Energy Planning and Policy**	**3 cr.**
EECE 675	**Renewable Energy Systems**	**3 cr.**
ENST 320	**Energy Laws and Case Studies**	**3 cr.**

MECH 513	**Air Conditioning**	**3 cr.**
MECH 603	**Solar Energy**	**3 cr.**
MECH 631	**Micro-Electro Mechanical Systems**	**3 cr.**
MECH 670	**Laboratory for Renewable Energy in Buildings**	**3 cr.**
MECH 672	**Modeling Energy Systems**	**3 cr.**
MECH 673	**Energy Efficient Building with Good Indoor Air Quality**	**3 cr.**
MECH 676	**Passive Building Design**	**3 cr.**
MECH 677	**Heat Pumps**	**3 cr.**
MECH 679	**Energy Audit Lab**	**3 cr.**
MECH 681	**Green Building Basics and LEED Practices**	

Course Descriptions

FEAA 200 Introduction to Engineering and Architecture 3 cr.
The course is designed to familiarize first year students with the different disciplines in Engineering and Architecture, including: Architecture, Civil, Mechanical, Electrical, Chemical, Industrial and technologies used in the fields. The course takes a unique interdisciplinary approach to the field and introduces the related disciplines in the world of engineering and architecture. One key objective is to promote interdisciplinary interaction and innovative thinking. The course is organized into modules covering the different disciplines within the Maroun Semaan Faculty of Engineering and Architecture (MSFEA). The last module of the class showcases interdisciplinary projects demonstrating interactions among the different fields. The lectures explain as applicable to each discipline, through examples, notions of problem solving, design thinking, process of invention and innovation, environmental and civic responsibility, and measures of success in aesthetics and performance. The course project is a key component of the course. It is interdisciplinary in nature bringing ideas and solutions from all disciplines in engineering and architecture. *Annually.*

MECH 201 Computer Aided Drawing and Design (CADD) 3 cr.
The course aims to prepare Mechanical Engineering students to communicate through graphics, technical drawings and design databases via Computer Aided Drawing (CAD) software (such as AutoCAD®) and 3D Computer Aided Design software (such as Creo Parametric). Orthographic projection, auxiliary views, sectional views, dimensioning and tolerancing, drawing formats. Part geometric construction. Assemblies and exploded assemblies. Parts and assemblies working drawings. Engineering symbols. CADD project.

MECH 220 Engineering Graphics 1 cr.
The course aims at preparing the future engineer to understand and create technical drawings. The course seeks to develop effective utilization of computer-aided drafting (CAD) skills in order to create engineering drawings: orthogonal projection, exploded and auxiliary views, sectioning and sectional views, dimensioning and tolerance schemes, standard drawing formats and detailing. Introduction to the use of CAD packages (AutoCAD).

MECH 230 Dynamics 3 cr.
This is a basic course in engineering mechanics covering dynamics of particles and planar rigid bodies. This course introduces Newton's law of motion, the principle of work and energy, and the principle of impulse and momentum. Diagrammatic representations of the basic laws are applied on motion of particles, systems of particles and rigid bodies. *Prerequisites: CIVE 210 and MATH 201.*

MECH 310/ CHEN 214 Thermodynamics I 3 cr.
This course seeks to provide a methodology by which students view objects in the physical universe as systems and apply to them the basic laws of conservation of mass, energy and entropy balance. The course covers the thermodynamic state and properties of a pure substance, energy and mass conservation, entropy and the second law. Applications involve closed setups and flow devices. Simple vapor and gas cycles applications.

MECH 314/ CHEN 311 Introduction to Fluids Engineering 3 cr.
An introductory course on fluid behavior emphasizing conservation of mass, momentum, energy and dimensional analysis; study of fluid motion in terms of the velocity field, fluid acceleration, pressure field and viscous effects; applications of Bernoulli's equation, Navier-Stokes and modeling; flow in ducts, potential flows and boundary layer flows. *Prerequisite: MECH 310.*

MECH 320 Mechanics of Materials 3 cr.
A course that addresses the mechanical behavior of materials under different loadings such as axial, bending, transverse shear, torsion and combined loadings. Stress and strain transformation is discussed. Deflection of beams and buckling in columns are covered. *Prerequisites: MECH 201 and CIVE 210.*

MECH 332 Mechanics of Machines 3 cr.
A course that deals with the mechanization of motion, kinematics analysis of linkage mechanisms, synthesis of cam-follower mechanisms, gear terminology and types of gears, analysis and synthesis of gear trains, force analysis and introduction to linkage synthesis. *Prerequisite: MECH 230.*

MECH 340 Engineering Materials 3 cr.
The course introduces fundamental concepts in materials science as applied to engineering materials: crystalline structures; imperfections, dislocations and strengthening mechanisms; diffusion; phase diagrams and transformations; ferrous and non-ferrous metal alloys, ceramics and polymers; structure-property relationships; material selection case studies.

MECH 341 Materials Lab 1 cr.
The course seeks to accompany and compliment MECH 340 Engineering Materials. The laboratory sessions are designed to impart a qualitative and quantitative understanding of the mechanical properties of engineering materials. The laboratory sessions will also examine topics related to the microstructure of materials. *Corequisite: MECH 340.*

MECH 410L Thermal/Fluid Systems Laboratory 1 cr.
A series of experiments on basic thermodynamic cycles, psychrometry, combustion and elementary fluid mechanics, with special emphasis on the use of the computer as a laboratory tool for data acquisition, reduction, analysis and report preparation. *Prerequisite: MECH 310.*

MECH 412/ CHEN 411 Heat Transfer 3 cr.
The course seeks to impart an understanding of the fundamental concepts and laws of conduction, convection and radiation heat transfer and their application to the solution of engineering thermal problems. The course covers steady and transient heat conduction; extended surfaces; numerical simulations of conduction in one and two-dimensional problems; external and internal forced convection of laminar and turbulent flows; natural convection; heat exchanger principles; and thermal radiation, view factors and radiation exchange between diffuse and gray surfaces. The use of Matlab is integrated into homework assignments. *Prerequisite: MECH 314.*

MECH 414 Thermodynamics II 3 cr.
A course investigating the availability and work potential of systems; irreversibility; second law efficiency; availability; gas mixtures; air-conditioning; chemical reactions; high speed flow, nozzles and diffusers; environmental, economic and social implications. *Prerequisite: MECH 310.*

MECH 420 Mechanical Design I 3 cr.
This is an introductory course in machine design in which one learns how to determine the structural integrity of common machine components and to apply this knowledge within the context of machine design problems. Mechanical elements such as shafts, bearings, springs, welding joints and fasteners are studied with emphasis on their behavior under both static and fatigue loading. *Prerequisites: MECH 320 and MECH 340.*

MECH 421 Manufacturing Processes I 3 cr.
A course covering traditional material removal processes (machining and abrasion), CNC machining, as well as non-traditional material removal processes (EDM, ECM, thermal cutting, etc.); the science behind these technologies; assembly processes such as welding, brazing, soldering and fastening are also covered. The course emphasizes process capabilities and limitations, relative cost and guidelines for process selection; and design for manufacturing guidelines. This course contains hands-on exercises in a machine shop environment. *Prerequisites: MECH 320 and MECH 340.*

MECH 430/ CHEN 351 Process Instrumentation and Measurements 3 cr.
A course on general concepts of measurement systems; classification of sensors and sensor types; interfacing concepts; data acquisition, manipulation, transmission and recording; introduction to LABVIEW; applications; team project on design and implementation of a measuring device. *Prerequisites: PHYS 211 and EECE 312.*

MECH 432 Dynamic System Analysis 2 cr.
A course introducing dynamic modeling and analysis of mechanical electrical, thermal and fluid systems. The course integrates software to test and analyze the modeled systems. *Prerequisites: EECE 210 and CIVE 210.*

MECH 436 Control Systems 3 cr.
This course and lab teach the fundamentals of designing feedback control systems. As a prerequisite, students have taken an introductory course on modeling and (linear) analysis of dynamic systems (such as MECH 432). This course consists of a theory focused classroom component and application oriented weekly labs. Both components are graded separately and students have to pass both in order to pass the course. The theory-focused, lecture-based component familiarizes students with tools to analyze the performance of closed loop control systems and to alter their dynamics according to requirement specifications. As an outcome, students are able to choose appropriate control strategies from a repertoire of linear control concepts and can execute their appropriate design. The lecture course grade is 68% of the total grade. An application-oriented lab is conducted in conjunction with the course, where the use of Matlab/ Simulink for the analysis and design of control systems is practiced. Students have the opportunity to apply course concepts on practical examples and to conduct control experiments on hardware setups. Labview is used to interface with the hardware setups. The lab grade is 32% of the total grade. Students working in groups of three will develop a project in the second half of the term. *Prerequisites: EECE 210, MECH 430 and MECH 432.*

MECH 499 Undergraduate Research 3 cr.
This course provides undergraduate students with advanced standing the opportunity to participate in faculty-supervised research. Before registering, students must submit a proposal for approval by the supervising faculty member and the department; the proposal must describe the nature of the research, specific goals and deliverables at the end of the term. The course may be counted once as a technical elective. *Prerequisites: Completion of 65 required credits in the major and a cumulative average of 80 or a GPA of 3.2 or above.*

MECH 500 Approved Experience 1 b*.
This is an eight-week professional training course in mechanical engineering.

MECH 501 Final Year Project I 1 cr.
The aim of this course is to provide students with practical experience in some design aspects of mechanical engineering. Students, working in groups, write a literature survey of an assigned project, critically analyze its components and develop a bill of material necessary for the completion of the project. *Prerequisites: MECH 500, MECH 420 and MATH 251.*

MECH 502 Final Year Project II 4 cr.
A course in which students integrate their acquired knowledge to deliver the product researched and planned in MECH 501. *Prerequisite: MECH 501.*

MECH 503 Special Topics in Mechanical Engineering 3 cr.

MECH 510 Design of Thermal Systems 3 cr.
The course seeks to develop in students the ability to integrate rate mechanisms (i.e., heat transfer and fluid dynamics) into thermodynamic system modeling, and analyses and provides design opportunities through open-ended problems with explicit considerations of engineering economics, optimization, environmental impact, ethical concerns, manufacturability and sustainability. Teamwork experience and communication skills are highly stressed. Students will gain hands-on experience with the tools of investigation used for thermal and fluid systems and learn how to approach and solve problems typically encountered in engineering experimental work. *Prerequisites: MECH 410L, MECH 412 and MATH 251.*

MECH 511 Intermediate Fluid Mechanics 3 cr.
A course that deals with potential flow and boundary layer analysis; lift and drag; flow separation; the use of computational techniques to solve boundary layer problems; viscous internal channel flow and lubrication theory; one-dimensional compressible flow in nozzles and ducts; normal shock waves and channel flow with friction or heat transfer; fluid machinery including pumps and hydraulic turbines. *Prerequisites: MECH 314 and MECH 412.*

MECH 512 Internal Combustion Engines 3 cr.
A course that examines the fundamentals of internal combustion engine design and operation, with emphasis on fluid/thermal processes. Topics include analysis of the respiration, combustion and pollutant formation processes; heat transfer and friction phenomena; engine types and performance parameters; thermo-chemistry of fuel-air mixtures; use of engine cycle models for performance predictions; and social implications of motorization. *Pre- or corequisites: CHEM 202, MECH 414 and MECH 430.*

MECH 513 Air Conditioning 3 cr.
A course on human thermal comfort and indoor air quality; solar radiation; heating and cooling load calculations in buildings; air conditioning systems; air and water distribution systems; computer-based calculations. *Prerequisite: MECH 412.*

MECH 514 Gas Turbines 3 cr.
A course that introduces the thermodynamic and aerodynamic theory forming the basis of gas turbine design: shaft power cycles; gas turbine cycles for aircraft propulsion; turbofan and turbojet engines; design and analysis of centrifugal and axial flow compressors and turbines. *Prerequisites: MECH 314 and MECH 414.*

MECH 515 Steam Turbines 3 cr.
A course that deals with impulse and reaction steam turbines, steam turbine cycles, flow of steam in nozzles, design aspects of turbines stage losses and efficiency, velocity diagrams; impulse and reaction blading velocities; nucleation, condensation and two-phase phenomena in flowing steam; boiler room and its various equipment; the complete steam power plant; governors, electric generator and power transmission lines. *Pre- or corequisites: MECH 314 and MECH 414.*

MECH 516 Aerodynamics 3 cr.
A course on theoretical and empirical methods for calculating the loads on airfoils and finite wings by application of classical potential theory, thin airfoil approximations, lifting line theory and panel methods; wings and airplanes; application of linearized supersonic flow to supersonic airfoils; performance and constraint analysis; longitudinal stability and control. *Pre- or corequisites: MECH 314 and MECH 414.*

MECH 517 Hydraulic Turbines for Power Generation 3 cr.
This course presents the principles and development of hydraulic turbines with emphasis on the techniques for formulating and solving problems. The importance of the incoming flow direction will be stressed. The Pelton, or tangential flow, turbine will be studied in detail. The course will provide a brief introduction to cavitation. *Prerequisites: MECH 310 and MECH 410L.*

MECH 519 Compressible Flows 3 cr.
The objective of the course is to impart an understanding of the fundamental principles of steady and unsteady one-dimensional perfect-gas flow. Students learn about the behavior of homenergic and homentropic flow, develop an understanding of normal shock waves and homenergic flow in nozzles; learn how to analyze frictional homenergic flow in a constant-area duct and frictionless diabatic flow in a constant-area duct; and learn how to draw skeleton wave diagrams of wave processes. *Prerequisites: MECH 310 and MECH 314.*

MECH 520 Mechanical Design II 3 cr.
This is an advanced course in mechanical design. Students taking this course are expected to have a firm grasp in the fundamentals of failure theories. This course proposes methods for designing and selecting components such as gears, belts, clutches, brakes, flywheels and journal bearings. A design project using a finite element package is emphasized. *Prerequisites: MECH 332 and MECH 420.*

MECH 521 Manufacturing Processes II 3 cr.
A course on heat treatments, deformation, phase-change and particulate consolidation processing of metals; fabrication processing of non-metallic engineering materials such as ceramics, polymers and composites; emphasis on process capabilities and limitations, relative cost and guidelines for process selection; the behavior of materials under processing conditions; design for manufacturing guidelines. This course emphasizes hands-on training exercises. *Prerequisite: MECH 340.*

MECH 522 Mechanical CAD/CAE/CAM 3 cr.
The course gives students exposure to the realm of computer-aided design (CAD), computer-aided engineering (CAE) and computer-aided manufacturing (CAM). The course teaches students to harness the power of these powerful tools in the solution of various problems of mechanical engineering. The course utilizes several commercially available software packages but the emphasis is placed on Pro/Engineer. *Prerequisites: MECH 320, MECH 420 and MECH 432.*

MECH 530/ EECE 560 Mechatronics System Design 3 cr.
A course that discusses mechatronics; data; numbering systems, architecture of the 8-bit Motorola MC68HC11 microcontroller, assembly language programming, A/D and D/A conversion; parallel I/O programmable timer operation, interfacing sensors and actuators, applications; a team project on design and implementation of a mechatronic system. *Prerequisites: EECE 312, MECH 430 or EECE 461.*

MECH 531 Mechanical Vibrations 3 cr.
A course on free and forced response of non-damped and damped system; damping vibration absorption; response of discrete multi-degree of freedom systems; modal analysis; vibration measurement, case studies, vibration analysis with Matlab and Simulink. *Prerequisite: MECH 230.*

MECH 532 Dynamics and Applications 3 cr.
This course examines the dynamics of particles and rigid bodies moving in three dimensions. Topics include Lagrange's equations of motion for particles, rotations of rigid bodies, Euler angles and parameters, kinematics of rigid bodies and the Newton-Euler equations of motion for rigid bodies. The course material will be illustrated with real examples such as gyroscopes, spinning tops, vehicles and satellites. Applications of the material range from vehicle navigation to celestial mechanics, numerical simulations and animations. *Prerequisite: MECH 230.*

MECH 533 Electric Machines and Drives 3 cr.
This course covers the fundamentals of electromagnetic circuits, three-phase circuits, transformers: single-phase ideal and real transformers, construction and operation; fundamentals of AC machines, operation of synchronous generators; induction motors: construction and principle of operation, power, torque and efficiency expressions; AC drives: starting and speed control strategies, plugging and regenerative breaking; DC motors types and control strategies, stepper motors: types, operational characteristics, drivers configurations. *Prerequisites: EECE 210 and MECH 310.*

MECH 535 Fluid Power Systems 3 cr.
This is a senior level undergraduate lecture course which covers the fundamentals of fluid power transmission and drive technology. Students learn about the main hydraulic and pneumatic components and their static and dynamic performance characteristics. Students learn how to read circuit diagrams and understand the principles of circuit operation. Through the use of simulation software, students will learn to design and analyze complex fluid power systems. *Prerequisites: MECH 314 and MECH 436.*

MECH 540 Selection and Properties of Materials 3 cr.
A course that reviews the mechanical behavior of materials. Topics covered include structure-property relationships in materials; continuum mechanics and tensor notation; theorems of elastic, plastic, viscoelastic behavior of materials; elements of creep, fatigue and fracture mechanics. *Prerequisite: MECH 340.*

MECH 550 Computer Applications in Mechanical Engineering 3 cr.
A course dealing with the application of numerical techniques for the solution of a variety of mechanical engineering problems involving systems of linear or nonlinear algebraic equations, systems of ordinary differential equations of the initial and boundary value types, systems of ordinary differential equations, and partial differential equations of the parabolic, elliptic and hyperbolic types. Engineering applications are introduced through a number of case study problems. *Prerequisites: MATH 202 and MATH 251.*

MECH 555/ EECE 463 Artificial Intelligence for Control Systems 3 cr.
This is an introductory course in the evolving field of artificial intelligence (AI) for control systems. It aims at giving students a solid foundation in AI by covering basic techniques such as A* searching, reasoning under uncertainty, probabilistic reasoning over time, multi objects tracking, path planning, scheduling, communicating,

perceiving and learning as applied to control systems, robotics and manufacturing. The group project and individual lab assignments will provide students with hands-on implementation experience of an intelligent control agent capable of basic learning. *Prerequisite: EECE 460 or MECH 436*.

MECH 600/ CHEN 690 **Reservoir Engineering** **3 cr.**
This course will cover both fundamental and applied reservoir engineering concepts. It aims at understanding the rock and fluid properties and how these properties interact to affect production from a hydrocarbon reservoir. From a practical standpoint, the course will focus on classical reservoir engineering, reservoir drive mechanisms, well testing and well test analysis as well as the use of reservoir simulation to assist the reservoir engineer at different stages of a hydrocarbon reservoir lifecycle. *Prerequisites: MECH 310 and CHEN 490*.

MECH 602 **Energy Conservation and Utilization** **3 cr.**
A course that deals with methods for reduction of losses and gains from a building envelope, energy conservation in cooling, heating, air-handling, and plumbing systems, energy management program. *Prerequisites: MECH 310 and MECH 412*.

MECH 603 **Solar Energy** **3 cr.**
A course discussing the fundamentals of solar radiation, collectors and concentrators, energy storage, estimation and conversion formulas for solar radiation. *Prerequisite: MECH 412*.

MECH 604 **Refrigeration** **3 cr.**
A course on fundamental concepts and principles, cold storage; functions and specifications of refrigeration equipment, applications. *Prerequisite: MECH 412*.

MECH 606 **Aerosol Dynamics** **3 cr.**
This course covers the physical and chemical principles that underlie the behavior of aerosols—collections of solid or liquid particles, such as clouds, smoke, and dust, suspended in gases—and the instruments used to measure them. Topics include: aerosol particle characterization; transport properties and phenomena in quiescent, laminar, and turbulent flows; gas- and particle-particle interactions; and applications to human respiratory tract deposition and atmospheric pollution. *Prerequisites: MECH 314, MECH 412 and MECH 414; or consent of instructor.*

MECH 607 **Micro Flows Fundamentals and Applications** **3 cr.**
A course on the theory and applications of micro flows; the continuum hypothesis and the various flow regimes; shear and pressure driven micro flows; electrokinetically driven liquid micro flows; compressibility effects of the micro flow of gases; particulate flows in bio-applications; modeling techniques; hybrid continuum-molecular methods; reduced order modeling of micro flows in multi-physics micro flow applications; case studies in BioMEMS. *Prerequisites: MECH 310, MECH 314 and MECH 412; or equivalent.*

MECH 608 **Applied Reservoir Engineering II** **3 cr.**
This course introduces the advanced concepts and principles needed to analyze hydrocarbon reservoir fluid systems, and defines the size and contents of petroleum accumulation. Students will learn to organize programs for collecting, recording and analyzing data describing the advanced characteristics of individual well and reservoir

performance. This course of advanced reservoir engineering topics covers a variety of topics such as: fluid flow in a porous medium; fluid distribution, fluid displacement; fractional flow equation; Buckly-Leverete equation; pressure draw-down and pressure buildup analysis; in addition to the nature and type of primary, secondary and tertiary recovery, water influx and prediction of water-flood behavior, reservoir model simulation and history matching. *Prerequisite: MECH 600.*

MECH 609 Experimental Methods in Fluid Dynamics 3 cr.
This is a graduate level course that introduces students to experimental methods used to measure fluid flow quantities such as pressures, forces and velocities. The course starts with an introduction to what and why we measure, uncertainty analysis and measurement error estimation. Some basic techniques for data reduction and data post-processing are introduced. The available fluid measurement methods are surveyed briefly, with selected applications. Emphasis is on advanced optical diagnostic techniques; namely particle image velocimetry (PIV) and laser induced fluorescence (LIF). The theoretical foundations of these techniques are established and the discussion extended to practical considerations, including software and hardware components. A few laboratory sessions are incorporated into the course to supplement the lectures and make use of the instruments available in the ME department, including the open circuit wind tunnel and the PIV system. In addition to the lectures and lab sessions, there is emphasis on the available literature. Prior knowledge of the basic principles of fluid mechanics and fluid systems is required. MATLAB is needed for coursework. *Prerequisite: MECH 314.*

MECH 615 Continuum Mechanics 3 cr.
The course offers a unified presentation of continuum mechanics such as fluids, elasticity, plasticity and viscoelasticity. The general concepts and principles applicable to all continuous media are presented followed by defining equations for a particular medium. Topics include fundamentals of tensor calculus, stress, deformation and strain, general principles, constitutive equations for solids and fluids.

MECH 617 Smart Materials and Structures 3 cr.
This course presents the fundamentals of modeling, analysis, and design of smart materials and structures. Students will be exposed to the state of the art of smart materials and systems, spanning piezoelectrics, shape memory alloys, electroactive polymers and fiber optics. Students will explore the application of such materials in structural systems from the aeronautic, automotive, biomedical and nautical industry. Smart materials are a class of materials varying in chemical composition and physical state that have one or more physical or physiochemical properties that can be significantly changed by external stimuli, such as pressure, temperature, electric or magnetic field, etc. Each student will participate in a group project. Under the guidance of the professor, the student will learn to develop a proposal, do the project investigation and prepare and carry out the technical communications (writing and oral). In any of these scenarios, the student is directly responsible for the progress and quality of the results. At the end of the term, the student is required to submit a written project report and to give a seminar presenting the aims and achievements of the project.

MECH 618 Enterprise Resource Planning (ERP) in Manufacturing Systems 3 cr.
This course will cover how today's industries can cope with the challenges induced by global competition. The course will address: challenges of today's industry; consequences of these challenges on product design and organizations; the role of the information systems, PLM, ERP and APS; and practice of PLM and ERP systems on the SAP Business Suite and Business by Design solution.

MECH 619 Quality Control in Manufacturing Systems 3 cr.
The course covers the foundations of modern methods of quality control and improvement that may be applied to manufacturing industries. It aims to introduce students to the tools and techniques of quality control used in industrial applications, and develop their ability to apply the tools and techniques to develop solutions for industrial problems. Emphasis is on the application of quality management techniques to solve industrial case problems. The course emphasizes the philosophy and fundamentals of quality control, the statistics foundations of quality control, statistical process control, acceptance sampling, and product and process design. *Prerequisites: STAT 230 and MECH 421.*

MECH 622 Modeling of Machining Processes and Machines 3 cr.
This course covers the principles and technology of metal machining; mechanics of orthogonal and 3D metal cutting; static deformations, forced and self-excited vibrations and chatter; and design principles of metal cutting CNC machines. *Prerequisite: MECH 421.*

MECH 624 Mechanics of Composite Materials 3 cr.
A course on anisotropic elasticity and laminate theory, analysis of various members of composite materials, energy methods, failure theories and micromechanics. Materials and fabrication processes are introduced. *Prerequisites: MECH 320 or CIVE 310, and MECH 340; or equivalent.*

MECH 625 Fatigue of Materials 3 cr.
A course that deals with high cycle fatigue; low cycle fatigue; S-N curves; notched members; fatigue crack growth; cycling loading; Manson-Coffin curves; damage estimation; creep and damping. *Prerequisite: MECH 320 or CIVE 310.*

MECH 626 Metals and Their Properties 3 cr.
A course that investigates ferrous and non-ferrous alloys; industrial equilibrium diagrams; heat treatment of metals; surface properties of metals; plastic deformation of metals; elements of fracture mechanics; process-structure-properties relations. *Prerequisite: MECH 340.*

MECH 627 Polymers and Their Properties 3 cr.
A course on chemistry and nomenclature, polymerization and synthesis, characterization techniques, physical properties of polymers, viscoelasticity, and mechanical properties and applications. *Prerequisite: MECH 340.*

MECH 628 Design of Mechanisms 3 cr.
A course involving graphical and analytical synthesis of single- and multi-loop linkage mechanisms for motion, path and function generation through 2-3-4- and 5-precision positions; optimum synthesis of linkage mechanisms; synthesis of cam-follower mechanisms; synthesis of gear trains. *Prerequisite: MECH 332.*

MECH 630 Finite Element Methods in Mechanical Engineering 3 cr.
A course on the classification of machine components; displacement-based formulation; line elements and their applications in design of mechanical systems; isoparametric formulation; plane stress, plane strain, axi-symmetric, and solid elements and their applications; modeling considerations and error analysis; introduction to potential energy and Galerkin approaches; and analysis of field problems. *Prerequisites: MECH 420 and MATH 251.*

MECH 631 Micro Electro Mechanical Systems (MEMS) 3 cr.
A course that deals with materials for micro-sensors and micro-actuators, materials for micro-structures, microfabrication techniques and processes for micromachining, computer-aided design and development of MEMS, commercial MEMS structures and systems, packaging for MEMS, future trends, and includes a team project. *Prerequisite: MECH 430.*

MECH 632 Structural Health Monitoring 3 cr.
The general concepts of structural health monitoring will be introduced. The commonly used techniques to provide continuous monitoring will be discussed (vibration and ultrasonic wave based methods). Further, determination of critical measurement types and location; data acquisition systems and instruments; design of measurement setup will be discussed. Handling data with advanced machine learning algorithm, such as artificial neural networking and support vector machine will be introduced. Students will also be introduced to the damage detection and condition assessment process. *Prerequisites: MECH 320 and MECH 430.*

MECH 633 Biomechanics 3 cr.
A course on the study of biomechanical principles underlying the kinetics and kinematics of normal and abnormal human motion. Emphasis is placed on the interaction between biomechanical and physiologic factors (bone, joint, connective tissue, and muscle physiology and structure) in skeleto-motor function and the application of such in testing and practice in rehabilitation. The course is designed for senior level undergraduate/graduate Engineering students with no previous anatomy/physiology. *Prerequisite: MECH 320 or CIVE 310, or consent of instructor.*

MECH 634/ BMEN 608 Biomaterial and Medical Devices 3 cr.
A course that examines the structure-property relationships for biomaterials and the medical applications of biomaterials and devices. The first part of the course focuses on the main classes of biomaterials, metal, ceramic, polymeric and composite implant materials, as well as on their interactions with the human body (biocompatibility). The second part examines the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatological and dental applications. Experts from the medical community will be invited to discuss the various applications. *Prerequisite: MECH 340 or consent of instructor.*

MECH 635/ BMEN 601 Computational Modeling of Physiological Systems 3 cr.
This course focuses on the quantitative modeling of different physiological systems. It provides students with current concepts of the mathematical modeling, and different quantitative descriptions of cellular and organ physiology. At the subcellular/cellular level, we will examine mechanisms of regulation and homeostasis. At the system level, the course will cover basic aspects of anatomical and pathophysiological features of the nervous, neural, cardiovascular and respiratory systems. Several physiological processes are treated as case studies for increasing complexity in modeling dynamical systems. *Prerequisites: MATH 202, or consent of instructor.*

MECH 637 Micromechanics and Crystal Plasticity 3 cr.
This course covers theoretical knowledge of the deformation process in single and polycrystalline solids with an emphasis on the role of dislocations and other types of defects on the overall mechanical properties of materials. Topics will include an introduction to crystallography, defects in crystals, fundamentals of dislocations, strengthening mechanisms, microstructures and yielding. *Prerequisites: MECH 340 and MECH 320.*

MECH 641/ EECE 661 Robotics 3 cr.
A course discussing concepts and subsystems; robot architecture; mechanics of robots: kinematics and kinetics; sensors and intelligence; actuators; trajectory planning of end effector motion; motion and force control of manipulators; robot languages. *Prerequisite: MECH 436 or EECE 460.*

MECH 642/ EECE 692 Computer Vision 3 cr.
An introductory course on the problems and solutions of modern computer vision. Topics covered include image acquisition, sampling and quantization; image segmentation; geometric framework for vision: single view and two-views; camera calibration; stereopsis; motion and optical flow; recognition; pose estimation in perspective images. *Prerequisites: MATH 202 and EECE 230 or EECE 231.*

MECH 643 Mechatronics and Intelligent Machine Engineering II 3 cr.
A course on sensors, sensor noise and sensor fusion; actuators; system models and automated computer simulation; information, perception and cognition; planning and control; architectures, design and development. A team project is included. *Prerequisites: MECH 340 and MECH 530.*

MECH 644 Modal Analysis 3 cr.
A course reviewing MDOF system vibrations, frequency response functions, damping, mobility measurement, curve fitting and modal parameter extraction; derivation of mathematical models, laboratory experiments and projects are included. *Prerequisite: MECH 531.*

MECH 645 Noise and Vibration Control 3 cr.
A course on fundamental concepts in noise and vibration, passive and active damping strategies, damping materials, control methods and applications. *Prerequisites: MECH 230, MATH 212 and MECH 531.*

MECH 646/ EECE 697 Wheeled Mobile Robotics 3 cr.
A course that provides in-depth coverage of wheeled mobile robots. The material covers: nonholonomy and integrability of kinematic constraints; modeling: kinematics, dynamics and state-space representation; and nonlinear control strategies (open-loop and closed-loop). Five case studies are covered throughout the course: car-like, cart-like, omni- directional wheeled, mobile wheeled pendulums and bike-like robots. *Prerequisite: Senior or graduate standing.*

MECH 647 Hydraulic Servo Systems 3 cr.
A graduate lecture course which covers the fundamentals of modeling and control of hydraulic servo-systems. It provides theoretical background and practical techniques for the modeling, identification and control of hydraulic servo-systems. Classical and advanced control algorithms are discussed. The use of Matlab/Simulink and DYMOLA will be an integral part in this course. *Prerequisites: MECH 314 and MECH 436, or MECH 314 and EECE 460.*

MECH 648 Nonlinear Systems: Analysis, Stability and Control 3 cr.

This course presents a comprehensive exposition of the theory of nonlinear dynamical systems and its control with particular emphasis on techniques applicable to mechanical systems. The course will be punctuated by a rich set of mechanical system examples, ranging from violin string vibration to jet engines, from heart beats to vehicle control, and from population growth to nonlinear flight control. *Prerequisite: MECH 436 or EECE 460.*

MECH 650/ Autonomous Mobile Robotics 3 cr.
This course is designed to provide engineering graduates and fourth year students with the opportunity to learn about autonomous mobile robotics. Topics include sensor modeling, vehicle state estimation, map-based localization, linear and nonlinear control, and simultaneous localization and mapping. *Prerequisites: EECE 230, EECE 312 and MECH 435; or EECE 230 and EECE 460.*

MECH 653/ System Analysis and Design 3 cr.
A course that outlines state-space models of discrete and continuous, linear and nonlinear systems; controllability; observeability; minimality; Eigenvector and transforms analysis of linear time invariant multi-input multi-output systems; pole shifting; computer control; design of controllers and observers. *Prerequisite: MECH 436 or EECE 460 or equivalent.*

MECH 654/ Adaptive Control 3 cr.
A course that includes the control of partially known systems; analysis and design of adaptive control systems; self-tuning regulators; model reference adaptive control of uncertain dynamic systems; typical applications. *Prerequisite: EECE 460 or MECH 436, or consent of instructor.*

MECH 655/ Optimal Control 3 cr.
A course on optimization theory and performance measures, calculus of variations, the maximum principle, dynamic programming, numerical techniques, LQR control systems. *Prerequisite: Senior or graduate standing, or consent of instructor.*

MECH 656/ EECE 663 **System Identification** **3 cr.**

This course introduces fundamentals of system identification as the basic mathematical tools to fit models into empirical input-output data. While rooted in control theory, applications extend to general time-series modeling and forecasting, such as stock prices, biological data and others. Topics covered include nonparametric identification methods: time and frequency response analysis; parametric identification methods: prediction error methods, least squares, linear unbiased estimation and maximum likelihood; convergence, consistency and asymptotic distribution of estimates; properties and practical modeling issues: bias distribution, experiment design and model validation. *Prerequisite: Senior or graduate standing, or consent of instructor.*

MECH 663 **Computational Fluid Dynamics** **3 cr.**

A course that deals with discretization process in fluid dynamics, numerical approaches and applications, iterative and direct matrix methods and numerical implementation of turbulence models. *Prerequisites: MECH 314 and MECH 412.*

MECH 665 **Unsteady Gas Flow** **3 cr.**

A course examining equations of unsteady continuous adiabatic multidimensional flows, unsteady continuous one-dimensional flow of a perfect gas with and without discontinuities, applications and pressure exchangers. *Prerequisite: MECH 414.*

MECH 670 **Laboratory for Renewable Energy in Buildings** **2 cr.**

A laboratory course that investigates means of reducing building energy consumption first through green building design, giving consideration to building orientation, thermal massing, wind- and buoyancy-driven flows, "urban heat island" effects, and second, by retrofitting existing buildings with energy saving materials and devices such as window films, solar water heaters and green roofs. This course is offered because in Lebanon and the region, electricity consumption for building services accounts for a major portion of national energy use and greenhouse gas emissions. Students will measure and compare effects of various designs and retrofit interventions on the thermal performance, lighting and glare, and natural ventilation of model-scale buildings; and characterize performance of devices used in green building design. Lab assignments may vary by term but will normally include mathematical modeling and experimental measurement components organized around aspects of building physics. *Prerequisite: MECH 430.*

MECH 671 **Renewable Energy Potential, Technology and Utilization in Buildings** **3 cr.**

A course that covers the principles and utilization of solar (thermal and photovoltaic), wind and geothermal energy, as well as energy from biomass. Issues relevant to energy efficiency and energy storage are discussed (heat and power store, and bio-tanks). The course distinguishes between energy sources for large-scale, industrial/ commercial settings and those intended for smaller structures. The potential of using renewable energy technologies as a complement to and, to the extent possible, replacement for conventional technologies, and the possibility of combining renewable and non-renewable energy technologies in hybrid systems, are analyzed. Design aspects of active, passive, wind, bio-energy and photovoltaic energy conversion systems for buildings; and strategies for enhancing the future use of renewable energy resources are presented. The course will include several demonstrations of concept experiments. *Prerequisite: MECH 310. Students cannot receive credit for both MECH 671 and EECE 675 or ENST 300.*

MECH 672 Modeling Energy Systems 3 cr.
A course that covers indoor space thermal models. The course also deals with the analysis and modeling of building energy systems involving applications of thermodynamics, economics, heat transfer, fluid flow and optimization. The use of modern computational tools to model thermal performance characteristics of components of HVAC systems including chillers, recovery systems, flow control devices, heat exchanges, solar panels, dehumidification systems, boilers, condensers, cooling towers, fans, duct systems, piping systems and pumps. The course will use modern simulation tools extensively. *Prerequisite: MECH 310.*

MECH 673 Energy Efficient Buildings with Good Indoor Air Quality 3 cr.
The course covers energy consumption standards and codes in buildings; energy conservation measures in the built-in environment to enhance the building's energy efficiency while maintaining space thermal comfort and indoor air quality requirement; fundamental ventilation, indoor-air-quality, infiltration, natural and mechanical ventilation, importance and impact of indoor air quality on human health and energy performance of the building air conditioning system; and ASHRAE requirement for ventilation. Particular focus will be given to green energy alternative measures. An overview of the different heating, ventilation and air conditioning system designs is covered. Performance and energy consumption of the conventional air conditioning system (constant and variable air volume) as well as the hybrid integrated air conditioning systems will be discussed and compared. The course will include several demonstrations of concept experiments. *Prerequisite: MECH 310.*

MECH 674 Energy Economics and Policy 3 cr.
A course that aims at developing an understanding of practical analytical skills of energy economics and planning approaches taking into account the cost of impact on the environment. This course will cover fundamental concepts of economic issues and theories related to energy, such as economics of natural and energy resources, aggregate supply and demand analysis, and the interrelationship between energy, economics and the environment; as well as some important issues in energy policy. The course will also demonstrate the use of economic tools for decision-making in energy and environment planning and policy. It will explore the terminology, conventions, procedures and planning policy applications. It will also cover a number of contemporary energy and environmental policy issues, including energy security, global warming, regulations of energy industries, energy research and development, and energy technology commercialization. *Prerequisite: INDE 301. Students cannot receive credit for both MECH 674 and ECON 333.*

MECH 675 Building Energy Management Systems 3 cr.
A course that provides an opportunity for students to explore topics in energy management systems and management strategies for new and existing buildings; energy use in buildings; energy systems analysis and methods for evaluating the energy system efficiency; energy audit programs and practices for buildings and facilities; initiating energy management programs; guidelines for methods of reducing energy usage in each area in buildings; conservation of energy in planning, design, installation, utilization, maintenance; control and automation of the mechanical systems in existing and new buildings; air conditioning and ventilation systems in buildings; assessment and optimization of energy control strategies; prediction methods of economic and environmental impact of implemented control strategies and indoor settings. *Prerequisites: MECH 310 and MECH 412.*

MECH 676 Passive Building Design 3 cr.
A course that centers on issues surrounding the integration of sustainable and passive design principles into conceptual and practical building design. Topics will include: solar geometry, climate/regional limitations, natural lighting, passive design and sustainability initiatives, insulating and energy storing material, and bioclimatic design and concepts. Case studies will be used extensively as a vehicle to discuss the success/failure of ideas and their physical applications. The course will focus on the use of energy auditing/modeling methods as means to both design and evaluate the relative "greenness" of buildings, as well as to understand the global implications of sustainable buildings. The course will include several demonstrations of concept experiments. *Prerequisite: MECH 671.*

MECH 677 Heat Pumps 3 cr.
A course that focuses on heat pumps in low energy and passive buildings as well as ground source heat pump fundamentals, loop systems, open systems, soil/rock classification and conductivity, grouting procedures, and performance of ground source heat pumps in housing units; water loop heat pumps, inside the building, bore holes, design and optimization of heat pump plants, including heat sources for such plants, and cost effective design options will also be considered. The course includes study visits and seminars given by industry experts. *Prerequisite: MECH 310.*

MECH 678 Solar Electricity 3 cr.
A course that focuses on the solar cell: photo generation of current, characteristic current-voltage (I-V) curve, equivalent circuit, effect of illumination intensity and temperature: the Photovoltaic (PV) generator: characteristic I-V curve of a PV generator, the PV module, connections of modules, support, safeguards, shadowing; the PV system: batteries, power conditioning; PV systems: grid- connected and stand-alone systems, economics and sizing, reliability, applications; and manufacturing: preparation of crystalline silicon wafers, formation of contacts, coatings, construction of modules. The course will include several demonstrations of concept experiments. *Prerequisite: EECE 210.*

MECH 679 Energy Audit Lab 2 cr.
A course designed to give students hands-on experience in carrying out energy audit measurements and studies on buildings to identify possible savings through selected energy conservation measures. Students will carry out measurements to investigate ventilation, air conditioning equipment, lighting and other office and lab equipment. Students will then be introduced to Visual DOE or E-Quest to perform energy simulation of buildings. Such tools will then be used to carry out a full building simulation taking into consideration occupancy data, equipment, lights and building envelope. A base case of energy usage will thus be established and energy conservation is then applied to deduce possible savings and their economic value. *Pre- or corequisite: MECH 672.*

MECH 680 HVAC and Refrigeration Systems Lab 3 cr.
The focus is on HVAC design optimization and energy conservation measures in built-in environment. It includes concepts of district cooling/heating systems, dehumidification and personalized ventilation systems. This course has a major component of hands-on experience with building energy systems design, operation and efficiency. Students will learn how to use and develop test equipment and plan for assessing system performance. Experiments and lab projects will span a series of advanced modules on sustainable, energy-efficient HVAC and refrigeration systems as laboratory topics. Lab topics may vary every term. *Prerequisites: Advanced standing and MECH 310.*

MECH 681/ CIVE 686 **Green Buildings and LEED Practices** **3 cr.**

In this course, students are exposed to green building concepts, design and construction practices, and building rating systems, namely the LEED (Leadership in Energy and Environmental Design) system. Real-world LEED certified projects are considered to enforce conceptual information. The course will cover the equivalent of training modules offered by the US Green Building Council (USGBC). *Prerequisite: Consent of course coordinator.*

MECH 691 **Convex Optimization** **3cr.**

Advanced course that covers topics such as convex sets, convex functions, convex optimization problems, scalarization for vector optimization, duality theory, optimality conditions. Example problems include least-squares, maximum likelihood estimation, minimax, and extremal volume problems. *Prerequisite: Math 218.*