Department of Mechanical Engineering

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Assistant Professors:	Al-Hindi, Mahmoud; Asmar, Daniel; Azizi, Fouad; Liermann, Matthias; Oweis, Ghanem; Saad, Walid; Safieddine, Salem; Shammas, Elie; Shehadeh, Mutasem; Zeaiter, Joseph
Lecturers:	Abou Chakra, Hadi; Hassoun, Talal; Kasamani, Jihad; Najm, Wajih; Nasereddine, Mohammad; Rouhana, Natalie
Instructors:	Al Saidi, Abdul-Kader; El Chmeitelly, Rana; Jalgha,Bassam; Karaogklanian, Nareg; Kassis, Lina; Kablawi, Amer; Kfoury, Elie; Seif, Cherbel

Graduate Programs

Master's Programs

General Information

The Department of Mechanical Engineering offers two graduate master's programs, one leading to the degree of master of engineering, with a major in mechanical engineering, the other leading to the degree of master of mechanical engineering, with a major in applied energy.

Master of Engineering (ME), Major: Mechanical Engineering

In this program students may choose to concentrate in any of the following areas:

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

[P] Part time

The student is encouraged to select a concentration area of personal interest, the area of "major concentration." The master's degree requires a minimum of 21 credit hours of course work and a thesis that equals nine credits. Research is a time consuming process, and between 20 and 24 months are usually required to complete the master's degree. The student and the graduate adviser, in coordination with the thesis committee, develop a plan of study tailored to the student's specific interest and background. It is advisable that this plan be developed no later than the first month of the second semester of graduate work.

The required 21 course credit hours and thesis are distributed as follows:

- A mandatory three-credit course in applied mathematics. The math course or math-oriented course offered by other departments must be approved by the graduate student's adviser. Acceptable courses include, but are not limited to the following:

MECH 630	Finite Element Methods in Mechanical Engineering
MECH 663	Computational Fluid Dynamics
MECH 764	Advanced Topics in Computational Fluid Dynamics
ENMG 604	Deterministic Optimization Models
MATH 307	Topics in Analysis

- At least two advanced fundamental ("core") mechanical engineering three-credit courses from two concentrations other than the major concentration, and as approved by the student's graduate thesis adviser. The following is a list of the recommended core courses by concentration:

  Thermal and Fluid Sciences: MECH 701, MECH 760, MECH 761, MECH 762

  Design, Materials, and Manufacturing: MECH 624, MECH 720, MECH 721

  Mechatronics: MECH 643, MECH 645

- **Four technical courses** (12 credit hours). Of these a minimum of three courses (nine credit hours) must be completed in the area of major concentration, and as approved by the student's graduate adviser. It is advisable to make the selection in connection with the thesis topic. A maximum of three credit hours may be completed in other engineering graduate programs again subject to the approval of the graduate student's adviser. A student may register for one time in MECH 796, Special Projects in Mechanical Engineering. The following is a list of engineering technical courses by concentration.

  Thermal and Fluid Sciences: MECH 609, MECH 663, MECH 665, MECH 701, MECH 702, MECH 703, MECH 705, MECH 707, MECH 751, MECH 760, MECH 761, MECH 762, MECH 764, MECH 765, MECH 766, MECH 767, MECH 768, MECH 769, MECH 898.

  Design, Materials, and Manufacturing: MECH 622, MECH 624, MECH 625, MECH 626, MECH 627, MECH 628, MECH 630, MECH 631, MECH 633, MECH 634, MECH 641, MECH 642, MECH 720, MECH 721, MECH 729, MECH 736, MECH 740, MECH 898, EECE 601, EECE 602, EECE 605, EECE 606, EECE 632.

  Mechatronics: MECH 628, MECH 641, MECH 642, MECH 643, MECH 644, MECH 645, MECH 729, MECH 740, MECH 746, MECH 747, MECH 898, EECE 632, EECE 636, EECE 691, EECE 692, EECE 694.

- **Seminar Course:** MECH 797 (zero credit). Students must register for the course once per year.
- **Thesis:** MECH 799 (equivalent to nine credit hours) based on independent research.

Master of Engineering, Major: Applied Energy

The objectives of the master's program leading to the Master of Engineering: Applied Energy degree are for its graduates to be able to:

- Design and manage efficient energy systems for buildings with high-quality indoor environments.
- Integrate renewable energy technologies with conventional energy systems to improve sustainability of energy supply systems.
- Understand the economic, policy and regulatory frameworks within which decisions on sustainable energy utilization practices are made.
- Assess and evaluate the impact of new technical developments in energy systems on society, the environment, and the economy.

Program Structure

The master's degree with the thesis option will normally require between 20 to 24 months for completion.

The program consists of 30 credits distributed as follows:

- Nine credits of mandatory courses selected from the following list:

  MECH 671 Renewable Energy Potential, Technology, and Utilization in Buildings
  MECH 672 Modeling Energy Systems
  MECH 673 Efficient Buildings with Good Indoor Air Quality
  MECH 674 Energy Economics and Policy

- Six credits of lab and special courses, including a minimum of one graduate level lab course. Lab and special courses are defined as follows:

  A graduate lab course corresponds to two credits. Suggested labs include but are not limited to:

  MECH 670 Laboratory for Renewable Energy in Buildings
  MECH 679 Energy Audit Lab
  MECH 770 HVAC and Refrigeration Systems Lab

A special course is a block course or a seminar course that corresponds to one or two credits depending on its duration and content. Special courses could be offered by experts from local or international industry, or by visiting faculty members from partner universities.

- Nine credits of elective courses selected with the approval of the graduate student's advisor in any of the following areas: sustainable energy production from renewable sources, hybrid systems, and sustainable energy utilization practices in the context of buildings.

  The pool of approved technical elective courses includes:

  MECH 603, MECH 675, MECH 676, MECH 677, MECH 678, MECH 701, MECH 771, MECH 772, MECH 773, MECH 778.

The elective courses can be replaced by courses taken during an exchange semester at one of the energy program partner universities. A maximum of six credits can be counted from an exchange semester.

- **Seminar Course:** MECH 797 (zero credit). This is a pass fail course based on attendance and is offered at least once per year. Students must register for it each time it is offered.
- **Thesis:** MECH 799E (equivalent to six credit hours). The thesis must be based on independent research.

Requirements

A student applying for admission to a graduate program is only eligible if s/he has a bachelor of engineering degree with a mechanical engineering major or the equivalent. A student must also satisfy the requirements of the University and the Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of the university catalogue (see pp. 37, 43 and 225–226).

Doctor of Philosophy (PhD), Specialization: Mechanical Engineering

The Faculty of Engineering and Architecture offers a graduate program of study leading to the PhD degree with specializations in mechanical engineering.

General Information

The graduate curriculum offers students opportunities to develop levels of expertise and knowledge consistent with a career of technical leadership. The doctoral program emphasizes the acquisition of advanced knowledge and the fostering of individual experience of significant intellectual exploration.

The educational objectives of the PhD program are to develop

- Expertise in a core area of mechanical engineering;
- The ability to identify pertinent research problems, formulate and execute a research plan, and generate and analyze original research results;
- The ability to communicate those results through oral presentations and written publications; and
- The practice of independent learning and advancing knowledge.

Admission Requirements

Candidates for the doctoral degree program are expected to have an outstanding academic record demonstrated by a minimum undergraduate cumulative grade average of 80.0 according to AUB standards (3.0 GPA in a 4.0 grade system), and have completed a master's degree in mechanical engineering or a related discipline with a cumulative grade average of 85.0 according to AUB standards (3.33 GPA in a 4.0 grade system).

The application to the doctoral program follows the deadlines set by the Admissions Office. All applicants are required to take the General Exam section of the Graduate Record Examination (GRE) and submit their scores. Students other than AUB graduates and graduates of recognized colleges or universities in North America, Great Britain, Australia, and New Zealand are required to take the Test of English as a Foreign Language (TOEFL) and receive a minimum score of 600 if taken manually, or 250 if taken via computer. Admission to the PhD Program is upon the recommendations of the department and the FEA Graduate Studies Committee, and requires the approval of the AUB Board of Graduate Studies.

PhD Program Description

The PhD program in mechanical engineering requires a minimum of 18 credit hours of course work beyond the master's degree. The student must pass a two-part PhD Qualification Examination. In addition, the student must submit an original dissertation based on independent research that makes a significant contribution to his/her area of research. The dissertation is the principal component of the doctoral program, and the part that will serve as the major indicator of a candidate's abilities. A minimum of 30 credits registered as dissertation work is required.

Advisers

After admission into the department, a general adviser will be assigned to the PhD student to guide her/him with the initial selection of courses and to introduce the student to the various research areas in the department. The student must select a dissertation adviser by the end of the first semester after admission to the program. The student must seek the faculty members that are in the student's area of interest, and discuss with them possible research topics for the PhD dissertation. Once an adviser is identified, the student will develop a Proposed Program of Study that lists the courses the student intends to take and the proposed dates for the written and oral Doctoral Qualifying Examinations. The Proposed Program of Study must then be submitted to the ME Graduate Committee for approval.

Course Requirements

The PhD program requires a minimum of 18 credit hours of course work beyond the master's degree. The program is composed of three credit hours of advanced study in mathematics, nine credit hours of technical graduate level courses of advanced study in the student's area of research (major course area requirements), and six credit hours of courses in a minor specialization area of study, selected by the student, in a field different from the major field of study. The minor specialization, six credit hours of courses, must be taken outside of the Mechanical Engineering Department. The minor requirement could be satisfied through courses previously taken in the student's master's degree program. This however, will not reduce the required minimum of 18 credit hours of course work needed beyond the master's degree.

Mathematics Course Requirements

A three credit advanced course in mathematics is required from all doctoral candidates. The course must be approved by the adviser of the candidate. The mathematics course requirement is satisfied if the student has completed at least six credits of advanced courses in math beyond the bachelor's degree.

Major Course Area Requirements

At least nine credit hours of core courses of advanced study in mechanical engineering are needed to satisfy this requirement. The courses should be in the major research area of the student and must be approved by the student's graduate dissertation adviser. This will enable the doctoral candidate to pursue course work in direct support of his/her research. The course work must address all recommendations, made during the qualification period, by the student's adviser and dissertation committee.

The following major course areas are offered:

I. Thermal and Fluid Sciences
II. Mechatronics
III. Design, Materials, and Manufacturing

Minor Subject Requirements

The minor is a program of advanced study that will help the student to develop knowledge and some competence in an area other than the candidate's major field of study that is related to his/her research area. Two graduate courses (not less than six credits) must be taken in a coherent field that is different from the major field of study. These six credit hours of courses must be taken outside of the Mechanical Engineering Department (i.e. in other engineering or basic science departments); some of this requirement could be satisfied through coursework done during the student's master's degree program. This, however, will not reduce the required minimum of 18 credit hours of course work needed beyond the master's degree. All courses taken in this minor area must be at the graduate level and must be taken while the student is registered in a graduate program at the AUB. The minor subject must be approved in advance by the student's dissertation committee, and by the FEA Graduate Studies Committee. The approval of the department offering the minor should also be sought.

If the student chooses mathematics as his minor then the course taken to fulfill the mathematics course requirement will count towards the minor subject requirements.

PhD Qualification Examination

The qualification examination for admission to PhD candidacy has two parts. Part 1: the written qualification examination must be completed before the end of the second semester of enrollment in the doctoral program. Part 2: the oral qualification examination must be completed within one year following the completion of Part 1.

The purpose of the qualifying examination is to determine whether the applicant possesses the attributes of a doctoral candidate: mastery of the core mechanical engineering disciplines, ingenuity and skill in solving unfamiliar problems.

The oral and written qualifying examinations will be held at end of the fall and the spring semester every year.

The mechanical engineering faculty will review each student's performance in the qualifying examination and decide whether s/he passes or fails. Students who fail sections of Part 1 may be permitted to take that section of the examination again, in which case they must do so the next time it is offered. In no case will a student be allowed to repeat any section of this examination more than once.

Part 1: Written Qualification Examination

Students must demonstrate that they have mastered the concepts of advanced calculus, solution of differential equations, and computational methods.

The student must take four sections of the written qualification examination in four sub-disciplines that are normally selected from the list of topics below:

- Applied Mechanics
- Materials and Manufacturing Processes
- System Dynamics and Control
- Design
- Fluid Mechanics
- Thermodynamics
- Heat and Mass Transfer

Part 2: Oral Qualification Examination

Students must give a presentation on their proposed dissertation research area to a committee comprised of the dissertation adviser(s), the dissertation committee members, and other interested faculty. The proposed oral examination will include questioning by the committee to assess whether the candidate has sufficient background to perform research in their chosen area. The oral examination may include a component in the student's major core area of studies. The criterion for passing requires that the research topic is of PhD standard, original, clear in its contribution to existing knowledge, and that the proposed methodology is appropriate. A student who fails the oral qualification examination should repeat it within four months after addressing the comments of the dissertation committee compiled by the dissertation committee chair in the examination report.

Dissertation Requirements

Following successful completion of the first part of the qualifying examination, all PhD candidates must submit a dissertation proposal summarizing their dissertation problem and the planned approach. The purpose of the proposal is to inform the department and faculty, in a concise statement, of the candidate's research program and those involved in it. It should explain what the student intends to do and how s/he intends to go about it. The dissertation proposal must provide sufficient literature citations to indicate an awareness of previous work, and enough detail to show how the work is expected to advance knowledge in the field.

Doctoral Dissertation Committee

The dissertation committee should be composed of at least five members, one of whom should be from outside the department/program and one from outside the university. The adviser and at least three of the committee members must be of professorial rank. All members of the committee must hold a doctoral degree in a relevant field. The chair of the committee must be a full professor who is not the PhD thesis adviser (requirement of the Lebanese Ministry of Higher Education).

Members of the doctoral dissertation committee are recommended by the student's adviser and approved by the department, the Faculty Graduate Studies Committee, and the Board of Graduate Studies.

The doctoral dissertation committee approves the thesis topic, research plan, conducts the thesis proposal defense (Part II of the Qualifying Exam) and conducts the thesis defense. The thesis proposal and the selection of the thesis committee should be approved at least two semesters before the student defends his/her thesis. The PhD thesis topic, examining committee, and admission to candidacy require Board of Graduate Studies approval.

External Examiner

An external examiner of high standing from abroad will be nominated by the chair of the department in consultation with the dissertation adviser, to review the dissertation before the defense. Comments by the external examiner will be shared with the student. The student will then be given an opportunity to revise the dissertation and incorporate revisions in the work in a timely manner. The external examiner may choose to attend the dissertation defense and participate in the deliberations.

All PhD candidates must defend their dissertation in an oral examination, open to the community, in which a candidate is examined by his/her committee.

Course Plan for PhD Students

All courses that are offered for credit in the master's program will also be offered as graduate courses for those in the PhD program.

Math Requirement Courses

At least one math course offered outside the ME department and approved by the graduate student's adviser. Acceptable courses include:

MATH 307	**Topics in Analysis**
CMPS 354	**The Finite Element Method**
CMPS 350	**Discrete Models for Differential Equations**
CMPS 373	**Parallel Computing**

Note that in the Faculty of Arts and Sciences, 300 level courses are graduate courses.

Major Area Courses

Thermal and Fluid Sciences:

MECH 663, MECH 665, MECH 701, MECH 702, MECH 703, MECH 705, MECH 707, MECH 751, MECH 760, MECH 761, MECH 762, MECH 764, MECH 765, MECH 766, MECH 767, MECH 768, MECH 769, MECH 771, MECH 772, MECH 773, MECH 778, MECH 898.

Mechatronics:

MECH 628, MECH 641, MECH 642, MECH 643, MECH 644, MECH 729, MECH 740, MECH 746, MECH 747, and MECH 898, EECE 632S, EECE 636S, EECE 691C, EECE 692C, EECE 694C.

Design, Materials, and Manufacturing:

MECH 624, MECH 625, MECH 626, MECH 627, MECH 628, MECH 630, MECH 631, MECH 633, MECH 634, MECH 641, MECH 642, MECH 720, MECH 721, MECH 736, MECH 740, and MECH 898, EECE 601S, EECE 602S, EECE 605S, EECE 632S.

Seminar Course

Seminar Course: MECH 797 (no credit). The student must register for the course once a year. This is a pass fail course.

PhD Dissertation

MECH 899 PhD Dissertation: The dissertation is based on independent original research. A student is required to register for a minimum of 30 credits of dissertation work. A student may register for a maximum of twelve credits in any given semester. The student must submit a dissertation based on results of original, independent research. The PhD dissertation is expected to make a significant contribution in mechanical engineering. Upon completion of the dissertation and after its approval by the student's dissertation adviser, a final oral examination will constitute the dissertation defense.

Residence Requirements

The student must register for at least four semesters beyond the completion of the master's degree. Requirements for the degree of Doctor of Philosophy must be completed within a period of five years after starting graduate work beyond the master's degree. An extension will require the approval of the AUB Board of Graduate Studies.

Graduation Requirements

A student can graduate at the end of any academic semester in which s/he has satisfied the following requirements:

- Met the residence requirements and all pertinent AUB regulations
- Has at least one paper, based on his/her PhD dissertation, accepted in a peer reviewed technical journal, in addition to one refereed conference paper
- Passed all the required courses and completed the research credit requirements
- Attained a minimum cumulative course average of 85 beyond the master's degree and not be on probation
- Passed the Doctoral Qualifying Examinations
- Successfully defended a dissertation of original scholarly work
- Deemed worthy by the Faculty

Course Descriptions

MECH 600 Applied Reservoir Engineering I 3 cr.
This course introduces the concepts and principles needed to understand and analyze hydrocarbon reservoir fluid systems, and defines (with the help of geological and petrophysical principles) the size and contents of petroleum accumulations. Students will learn to organize programs for systematically collecting, recording, and analyzing data describing fundamental characteristics of individual well and reservoir performance (i.e. pressure, production, PVT data). The course covers topics on: fundamental concepts of fluid distribution, porosity distribution, trapping conditions; nature and type of primary drive mechanisms; production rates, ultimate recoveries, and reserves of reservoirs; supplementary recovery schemes to augment and improve primary recovery; economics analysis of developing and producing reservoirs, and conducting supplementary recovery operations. *Prerequisite: MECH 314 or CIVE 340*.

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; and energy management programs. *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.
A course covering the physical and chemical principles that underlie the behavior of aerosols--collections of solid or liquid particles suspended in gases, such as clouds, smoke, and dust--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 approval of instructor.*

MECH 607 Micro Flows Fundamentals and Applications 3 cr.
A course on 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
This course introduces the advance 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 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.
A graduate level course aimed at introducing 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, and 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 advance 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, emphasis is also on the available literature. Prior knowledge of the basic principles of fluid mechanics and fluid systems is required. MATLAB is needed for course work. *Prerequisite: MECH 314*.

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 given to 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 equivalents*.

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 ALGOR general formulation and Galerkin approach; and the analysis of field problems. *Prerequisites: MECH 431 and MECH 420*.

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 633 Biomechanics 3 cr.
A course on the study of the 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 engineering students with no previous anatomy/physiology. *Prerequisite: CIVE 210, MECH 320 or CIVE 310, or approval of instructor.*

MECH 634 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 their interactions with the human body (biocompatibility). The second part of the course examines the various applications of biomaterials and devices in different tissue and organ systems such as orthopedic, cardiovascular, dermatology, and dental applications. Experts from the medical community will be invited to discuss the various applications. *Prerequisite: MECH 340, or approval of instructor.*

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. *Prerequisites: MECH 332 and MECH 431*.

MECH 642 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*.

MECH 643 Mechatronics and Intelligent Machines 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. *Prerequisite: MECH 531*.

MECH 647 Hydraulic Servo Systems **3 cr.**
A graduate lecture course which teaches 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 431*.

MECH 648 Nonlinear Systems: Analysis, Stability, and Control **3 cr.**
A course that 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 431*.

MECH 660 Advanced Fluid Mechanics **3 cr.**
A course that examines fundamental concepts and principles in addition to basic relations for continuous fluids; Vorticity dynamics, Kelvin Helmholtz theorems; Navier-Stokes equations; Turbulence and Oscillating flows: *Prerequisite: MECH 314*.

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; 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 discontinuity, applications, and pressure exchangers. *Prerequisite: MECH 414*.

MECH 670 Laboratory for Renewable Energy in Buildings 2 cr.
A laboratory course that will investigate 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 semester 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*.

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 extensively modern simulation tools. *Prerequisite: MECH 310*.

MECH 673 Efficient Buildings with Good Indoor Air Quality 3 cr.
A course covering energy consumption standards and codes in buildings and energy conservation measures in 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, ASHRAE, 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 are also 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. *Pre- or co-requisite: MECH 672 or equivalent*.

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 provide 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: ENGM 400. 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 the energy in the 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, 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. 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 that is designed to give the students "hands-on" experience with carrying out energy audit measurements and studies on buildings to identify possible savings through selected energy conservation measures. The students will carry out measurements to investigate ventilation, air conditioning equipment, lighting and other office and lab equipment. The 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 co-requisite: MECH 672*.

MECH 701 Principles of Combustion 3 cr.
A course on gas-phase reaction mechanisms and thermo-chemical kinetics; theory of ignition, flame propagation, and detonation; characteristics of premixed, diffusion, laminar, and turbulent flames; combustion aerodynamics; liquid and solid fuels in practical systems; pollutant formation and reduction mechanisms. *Prerequisites: CHEM 202, MECH 412, MECH 414, or equivalents*.

MECH 702 Pollutant Formation and Control in Combustion 3 cr.
A course that covers the fundamentals of gas and condensed phase pollutant formation, measurement, and control pertaining to practical combustion systems. Topics include heat and mass transfer in reacting systems, chemical reaction kinetics, particle coagulation kinetics, and flame structure and propagation. These fundamental subjects are applied in the study of pollutant formation and control in practical systems including internal combustion engines, jet engines, and industrial boilers. Removal of gaseous and particulate pollutants from effluent streams by use of adsorption, absorption, catalytic processes, inertial separation, and electrostatic precipitators. *Prerequisites: MECH 310, MECH 410, MECH 412, CHEM 202, or approval of instructor. May be repeated for credit when topics vary*.

MECH 703 Combustion Modeling 3 cr.
A course that covers the following topics: chemical thermodynamics and chemical kinetics, conservation laws for reacting flow problems, diffusion controlled vs. chemistry controlled combustion, Laminar non-premixed and premixed flames and jets multi-phase combustion, detonations waves, turbulent combustion, and combustion stability. *Prerequisites: CHEM 202, MECH 310, MECH 412, or equivalents*.

MECH 705 Bioheat Modeling and Human Thermal Environments 3 cr.
This course is concerned with bioheat heat modeling of the human body and the human responses to hot, moderate, and cold thermal environments. A comprehensive and integrated approach is taken to mathematical modeling of heat transfer in the human body, heat and mass transfer from the human body while defining human thermal environments in terms of air temperature, radiant temperature, humidity and air velocity of the environment, the clothing, and the activity of the person. Other topics covered are bioheat modeling; mathematical analysis and computer modeling of human response to the thermal environment; interaction of environment parameters with physiological and psychological responses and impact on the human health, comfort, and performance; evaluation of heat stress and cold stress; thermal properties of clothing under static and active conditions; models for estimation of ventilation of clothed active persons; and international standards for the assessment of thermal comfort in the indoor environment. *Prerequisite: MECH 412*.

MECH 707 Statistical Mechanics and Thermodynamics 3 cr.
A course that examines the basic principles of statistical mechanics and their relation to the laws of thermodynamics and the concepts of temperature, work, heat, and entropy; the microcanonical, canonical, and grand canonical distributions; the applications to lattice vibrations, ideal gas, photon gas, quantum statistical mechanics; the Fermi and Bose systems, and interacting and non-interacting systems. *Prerequisite: MECH 310*.

MECH 720 Advanced Machine Design 3 cr.
A course that involves the analysis of stress and strain, torsion, design of axi-symmetrically loaded members, beams on elastic foundations, elastic stability, surface contact and wear, impact, and finite element applications to nonlinear problems. *Prerequisite: MECH 520*.

MECH 721 Elasticity and Plasticity 3 cr.
A course on tensor analysis, the general state of stresses, properties and deformation of solid materials, elasticity, plasticity, matrix methods, and applications. *Prerequisite: MECH 320 or CIVE 310*.

MECH 729 Spatial Mechanisms 3 cr.
A course that covers position, velocity, and acceleration analysis of spherical and spatial mechanisms; isometry; geometry of rotation axes; finite position synthesis, the 4R spherical linkage; lines and screws; the RSSR, RSSP, 4C, and 5TS spatial linkages; platform manipulators. *Prerequisite: MECH 628*.

MECH 736 Modeling Solidification Processes 3 cr.
A course that seeks to impart a coherent view of solidification processes and how they are modeled. Topics for the first part of the course include: homogeneous and heterogeneous nucleation, with plane front, cellular and dendritic pattern, columnar and equiaxed grain growth. Phenomena affecting the quality of castings such as micro-segregation, constituent under-cooling, macro-segregation and porosity formation are also covered. In the second part solidification models are developed and applied in the context of casting operations. The course covers: heat flow in solidification processes; thermodynamics of solidification: nucleation and growth; binary phase diagrams, phase diagram computation; microstructure evolution, constitutional under-cooling; columnar and equiaxed solidification enthalpy method; mushy zone modeling; phase-field method; volume-averaging of conservation equations; multi-scale models; and modeling solidification defects. *Prerequisites: MECH 340, and MECH 420, or approval of instructor*.

MECH 740 Advanced Dynamics 3 cr.
A course that examines three-dimensional kinetics and kinematics, theory of rotating axis, Hamilton's equations, Lagrange's equation, and Euler's equations. *Prerequisite: MECH 230 or equivalent*.

MECH 746 Space Mechanisms 3 cr.
A course that covers the following topics: mobility, spatial displacements, formulation of the kinematic equation, analysis and synthesis of spherical mechanisms, analysis and synthesis of spatial mechanisms, optimum synthesis of spherical and spatial kinematic chains, and analysis of platform manipulators. *Prerequisite: MECH 628*.

MECH 747 Nonlinear Finite Element Analysis 3 cr.
A course that covers governing equations and geometric and material nonlinearities; formulation of nonlinear problems; solution algorithms; vector and matrix methods; direct and iterative equations solvers; FE methods for nonlinear mechanics; element technology; numerical implementation of constitutive models; pitfalls of nonlinear analysis. *Prerequisite: MECH 630*.

MECH 751 Simulation of Multiphase Flows 3 cr.
A course that is intended to give an overview of the fundamentals involved in dispersed multiphase flows, and develop a working knowledge which would allow the student to predict these flows numerically. Multiphase flows are important to many engineering and environmental applications. The course examines the conservation equations for multiphase systems; discretization using the finite-volume method; pressure-based algorithms for multi-fluid flow at all speeds: mass conservation based algorithms and geometric conservation based algorithms (SIMPLE, SIMPLEC, PISO, etc.); the partial elimination and SINCE algorithms; weighted pressure correction; mutual influence of volume fractions; implicit volume fraction equations; bounding the volume fractions; numerical implementation; and applications. *Prerequisite: MECH 663*.

MECH 760 Advanced Fluid Mechanics 3 cr.
A course that examines fundamental concepts and principles, basic relations for continuous fluids, vorticity dynamics, Kelvin and Helmholtz theorems, Navier-Stokes equations, turbulent and oscillating flows. *Prerequisite: MECH 314 or equivalent*.

MECH 761 Convection Heat Transfer 3 cr.
A course that covers fundamental modes of heat transfer; similarity between heat, momentum, and mass transfer in forced and buoyancy-driven flows; simultaneous heat, momentum, and mass transfer with phase change. *Prerequisites: MECH 314 and MECH 412*.

MECH 762 Advanced Thermodynamics 3 cr.
A course on advanced thermodynamic concepts; gas mixtures and multi-phase systems; chemical reactions; thermodynamic property relations; chemical and phase equilibrium; applications. *Prerequisite: MECH 414*.

MECH 763 Radiative Heat Transfer 3 cr.
A course that deals with the principles of thermal radiation and their application to engineering heat and photon transfer problems. Quantum and classical models of radiative properties of materials, electromagnetic wave theory for thermal radiation, radiative transfer in absorbing, emitting, and scattering media, and coherent laser radiation. Applications cover infrared instrumentation, global warming, furnaces, and high temperature processing. *Prerequisite: MECH 412*.

MECH 764 Advanced Topics in Computational Fluid Dynamics 3 cr.
A course on numerical solution of compressible unsteady flows, advanced turbulence modeling, the segregated approach, the multigrid technique, and an introduction to multi-phase flows. *Prerequisite: MECH 663*.

MECH 765 Advanced Finite Volume Techniques 3cr.
A course that focuses on linear multigrid; non-linear multigrid; mesh agglomeration: structured and unstructured grids; mesh generation: structured and unstructured grids; free surface simulation; and solidification simulation. *Prerequisite: MECH 633*.

MECH 766 Turbulent Flow and Transport 3cr.
A course that covers the methods of analysis of turbulent fluid flow; in-depth discussion of algebraic, one-equation, and two-equation turbulence models; the power and limitations of turbulence models; and numerical implementation. *Prerequisite: MECH 660: Advanced Fluid Mechanics*.

MECH 767 Heat Conduction 3 cr.
A course on solutions of steady and transient heat conduction problems with various boundary conditions; approximate analytical methods; application of numerical techniques; moving boundaries, problems in freezing and melting; anisotropic and composite materials. *Prerequisite: MECH 412*.

MECH 768 Transport through Porous Media 3 cr.
A course designed for graduate students interested in the flow of multi-phase, multi-component fluids through porous media. The course emphasizes physics of the momentum, heat and mass transport formulation and computations in multi-dimensional systems, including theoretical models of fluid flow, capillary effects, application of fractal and percolation concepts, characterization of porous materials, multiphase flow and heat transfer, turbulent flow and heat transfer, improved measurement techniques, and enhanced design correlations. *Prerequisite: MECH 412*.

MECH 769 Advanced Scientific Computing 3 cr.
A course where students will learn how to solve and visualize large-scale continuum type problems using high-performance cluster-type computing systems. Sections of the course will concentrate on discretization methods, multigrid methods in a parallel computing context. Different parallel computing paradigms are introduced with emphasis on domain decomposition methods, and the practical aspects of their implementations using MPI. *Prerequisite: Prior knowledge of C programming and familiarity with the UNIX operating system*.

MECH 770 HVAC and Refrigeration Systems Lab 2 cr.
A course designed to give the students "hands-on" experience with building energy systems and expose them to basic and advanced methods of measurements and data analysis to design, test, and evaluate indoor climate conditions and HVAC system performance under appropriate control strategies for comfort and indoor air quality. The students will learn how to use and develop test equipment and plan for assessing system's performance according to ISO or ASHRAE standards. The students will be exposed to electrical HAVC instrumentation and hardware, IAQ testing equipment, tracer gas techniques for ventilation rates measurements, flow characterization measurements and air leakages and fenestration ratings. 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 semester. *Pre- or co-requisite: MECH 673*.

MECH 771 HVAC System Control Strategies and Energy Efficiency 3 cr.
A course that deals with the most common control strategies based on temperature set point, PMV control, CO2 set-point; and equipment used to reduce the amount of energy consumed by heating, ventilating, and air conditioning (HVAC) systems using non-derivative optimization techniques. Control strategies and technologies related to gaseous indoor air pollutants. The control strategies analyzed in the course are: scheduled start-stop, day-night setback, optimum start-stop, dead band control, duty cycling, demand limiting and load shedding, economizer and enthalpy cycles, scheduled temperature reset, chiller control and chilled water reset, boiler control and hot water temperature reset, and condenser water temperature reset. Recent developments in HVAC control system hardware, such as pneumatic systems, electro-pneumatic systems, digital-electronic systems, and microcomputer-based control systems, are also discussed. The strategies are studied and compared to each other in terms of cost effectiveness using optimization techniques. Case studies are used to strengthen understanding. *Prerequisites: MECH 431 and MECH 672*.

MECH 772 Moisture and Control of Humidity Inside Buildings 3 cr.
A course focusing on the following topics: sources of moisture and factors affecting its entry and buildup inside buildings, such as construction practices and choice of building materials and furniture; impact of moisture on thermal comfort and energy performance of the air-conditioning system; solid/liquid desiccant dehumidification and hybrid air-conditioning systems; modeling of moisture transport; industrial need to control indoor humidity; and moisture-caused health issues including mold formation and growth. The course will include several demonstrations of concept experiments. *Prerequisite: MECH 672*.

MECH 773 Numerical Methods in Energy Technology 3 cr.
A course that introduces the fundamentals of numerical methodology in energy related areas (CFD, Heat and mass transfer). Topics include: basic conservations equations; boundary conditions; finite volume discretization of conservations equations; geometry and computational mesh discretization practices; turbulence modeling (k-two-equation model); SIMPLE and SIMPLEC algorithms; thermal and solar radiation; and dispersed multiphase flow. The course emphasizes how to apply this information to the design and testing of related equipment. Individual and group assignments are given throughout the course to act as training aid and to enhance understanding. A class project is included to provide supervised practice on course material using commercial software. *Prerequisite: MECH 672*.

MECH 778 Special Projects on Renewable Energy Systems Design 3 cr.
A course that allows the student to take a given set of requirements and to select and design a complete renewable energy system to fully meet those requirements. The student will perform all aspects of the project design from cost-benefit analysis to systems specification to construction, control and final audit assessment of the completed energy system. The student is exposed to various commercially available design and simulation software for planning, specifying and simulation testing of renewable energy retro-fits and new installations. *Prerequisites: MECH 671 and MECH 672*.

MECH 788 (A-E) Thesis in Applied Energy 6 cr.

MECH 796 Special Projects in Mechanical Engineering 3 cr.

MECH 797 Seminar 0 cr.
A seminar that consists of weekly presentations on current research or applied projects in mechanical engineering presented by faculty, students, and invited scholars. This is a pass fail course based on attendance.

MECH 798 Special Topics in Mechanical Engineering 3 cr.

MECH 798A Fundamentals of Energy and Resource Recovery 1 cr.
A course covering the following topics: combustion and the environmental impact of combustion; fundamentals in energy and material balances; basic knowledge of the kinetics and the influence of different flow models; and humidification and vapor liquid equilibrium. *Prerequisite: MECH 310*.

MECH 798B Energy Recovery 1 cr.
A course that aims to give the students extended knowledge on various techniques for energy recovery by combustion. Topics include combustion devices, fluidized bed boilers, grate boilers, biogas boilers, energy recuperation and recovery technology, effects of inorganic compounds in the fuel, fuel and ash treatment, fouling and agglomeration; and the fundamentals of metals, oxidation phenomena, high temperature corrosion, and erosion-corrosion. *Prerequisites: MECH 310 and MECH 340*.

MECH 798C Sustainable Materials 1 cr.
A course that aims to give the student knowledge regarding sustainable materials, and their use in the product development cycle in order to promote sustainability. The course covers the development and economy of industrial materials; the interaction between materials and environment; and materials and public health. Alternative strategies for material use are also covered such as: recycling and reuse, renewable materials and biodegradable materials. Finally the importance of: legislation and governmental policies in promoting sustainability in society is reviewed. Assignments will be in the form of case studies. *Prerequisite: MECH 340*.

MECH 798D Moisture Transport in Building Envelopes 2 cr.
A course that deals with the sources of moisture affecting building envelops; rain, water vapor in outside and inside air, condensation and water uptake from the foundation; factors affecting the entry and buildup of moisture such as construction practices, choice of building materials and surface treatments; impact of moisture on heat transport through the envelopes, modeling of moisture transport; and moisture-caused damages including mould growth, decay of construction materials paintings etc. *Prerequisite: MECH 672*.

MECH 798E Computer Modeling and Building Physics Applications 2 cr.
A course on computer modeling of temperature and moisture conditions in building materials and components is essential in order to evaluate the performance of the building envelope, which is decisive for the indoor climate, the consumption of energy, and the durability of the construction. These are important factors for low environmental impact and sustainable building technology. Focus will be put on understanding and using computer models for building physics applications. Theory of mathematical and numerical modeling of heat and mass transfer and an overview of existing calculation tools combined with practical exercises will be given. A simple calculation tool will also be developed within this course. *Prerequisite: MECH 672*.

MECH 798F Contemporary Topics in Energy Management 2 cr.
This course provides students with the basics of the interrelationships between energy, economy, and the environment. It highlights the global and regional energy scenes. The module provides students with the fundamentals of energy and carbon accounting, energy management, and energy efficiency. It will cover policies and measures to shift towards low carbon economy, and demonstrate approaches used in assessing these measures. *Prerequisite: MECH 310*.

MECH 799 (A-E) Thesis in Mechanical Engineering 9 cr.

MECH 799T and 799TR Master's Comprehensive Exam 0 cr.
The master's degree comprehensive exam grading mode is Pass/Fail. If a student fails MECH 799T s/he must register for MECH 799TR and take the exam during the next term excluding summer.

MECH 898 Advanced Topics in Mechanical Engineering 3 cr.

MECH 900 and 900A PhD Comprehensive Exam 0 cr.
The PhD comprehensive exam grading mode is Pass/Fail. If a student fails MECH 900 s/he must register for MECH 900A.

MECH 990 PhD Dissertation

MECH 991 PhD Dissertation 3 cr.

MECH 992 PhD Dissertation 6 cr.

MECH 993 PhD Dissertation 9 cr.

MECH 998 and 998A PhD Defense of Thesis Proposal 0 cr.
The defense of the PhD thesis proposal has a grading mode of Pass/Fail. If a student fails MECH 900 s/he must register for MECH 900A. *Prerequisite: MECH 900 or MECH 900A with a pass.*

MECH 999 and 999A PhD Thesis Defense 0 cr.
The PhD thesis defense has a grading mode of Pass/Fail. If a student fails MECH 999 s/he must register for MECH 999A. *Prerequisite: MECH 998 or MECH 998A with a pass*.

Chemical Engineering Courses

CHEN 612 Desalination 3 cr.
A course that will provide an in depth coverage of the commonly used thermal and membrane based desalination technologies. Fundamental thermodynamic and transport processes which govern desalination will be developed. Environmental, sustainability and economic factors which may influence the performance, affordability and more wide-spread use of desalination systems for fresh water production and reuse will be highlighted. Renewable energy technologies coupled with desalination processes will be reviewed. A team based student project will be assigned to design a reverse osmosis membrane desalination plant (brackish water, seawater, or treated sewage effluent) using conventional or alternative energy sources. *Prerequisites: MECH 310, CHEN 411, or MECH 412.*

CHEN 613 Membrane Separation Processes 3cr.
The course will provide a general introduction to membrane science and technology: transport mechanisms, membrane preparation and boundary layer effects. The course will also cover the various types of membranes used in industry: microfiltration, ultrafiltration, reverse osmosis, electro-dialysis and pervaporation. *Prerequisite: CHEN 312.*

CHEN 614 Environmental Engineering Separation Processes 3cr.
This course includes a discussion of the unit operations associated with environmental engineering separation processes of solid-liquid, liquid-liquid and gas-liquid systems; general use, principles of operation and design procedures for specific type of equipment. *Prerequisite: approval of instructor.*

CHEN 617 Chemical Reactor Analysis and Design 3 cr.
This course covers design for optimum selectivity; stability and transient behavior of the mixed flow reactor; non-ideal flow and balance models; fixed and fluidized bed reactors; and multiphase flow reactors. *Prerequisite: CHEN 417.*

CHEN 618 Colloid and Interface Science 3 cr.
This is a first course in colloid and interface science. The repulsive and attractive forces at interfaces are described along with the dynamics of the interfaces. Topics include the stability of macroemulsions, the formulation and properties of microemulsions, and surface metal-support interactions of catalysts. *Prerequisites: CHEN 312 and CHEN 417.*

CHEN 651 Advanced Process Control 3cr.
This course covers the mathematical modeling and computer simulation of process dynamics and control. *Prerequisites: CHEN 451 and 451L.*

CHEN 672 Polymer Science 3 cr.
This course is a broad technical overview of the nature of synthetic macromolecules, including the formation of polymers and their structure, structure-property relationships, polymer characterization and processing, and applications of polymers. The course tends to focus on thermoplastic polymers and elastomers. *Prerequisite: MECH 340.*

CHEN 673 Engineering of Drug Delivery Systems 3 cr.
This course focuses on recent advances in the development of novel drug delivery systems. The fundamentals of drug delivery are discussed. Various strategies to tune and control the release of active agents for optimized therapeutic outcomes are explored. The course covers polymers and techniques used to produce drug nanoparticles, with specific examples of nanoparticle-based drug delivery systems. *Prerequisites: MECH 310, CHEN 411, and CHEM 204.*

CHEN 691 Reservoir Characterization: Carbonate Rocks 3 cr.
This course is an introduction to the common, modern approaches for the characterization of carbonate reservoirs. State of the art petrographic tools will be introduced. The major depositional environments of carbonate rocks and carbonate platform types as well as the principal controls on carbonate sedimentation will be highlighted. Diagenesis (modification of reservoir properties through time) will be discussed through related processes and products, including the process of dolomitization. An in depth coverage of secondary porosity evolution in carbonate reservoirs will be provided (including elements of appropriate rock-typing). A team based project to solve a case study in reservoir characterization and a field-trip to provide a practical view of carbonate reservoir rocks will be included. *Prerequisite: CHEN 490*.